Adult Psychiatric and Offending Outcomes of Paediatric Mild Traumatic Brain Injury

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ABSTRACT

Introduction: Mild traumatic brain injury (mTBI) accounts for the vast majority of all paediatric TBI cases. It is an important public health concern, yet the long-term psychiatric and behavioural outcomes remain imperfectly understood. **Aim.** This study aims to examine the association between paediatric mTBI and psychiatric and offending outcomes in adulthood, while considering the impact of sex, age at injury and duration since injury on outcome. **Participants:** Participants with mTBI (n=57) were compared to those with moderate/severe TBI (n=62) and to orthopaedic injury controls (n=42). All participants were injured at age 17 or younger and were 18 years or older at the time of assessment. **Outcome measures:** Based on the DSM-IV-TR criteria, structured interviews were used to assess participants' experience of symptoms consistent with major depressive disorder, anxiety disorders (including generalised anxiety disorder, panic attacks and panic disorder, agoraphobia, social phobia, post-traumatic stress disorder, and specific phobia), and substance abuse and/or dependence. Participants' were asked to report on their lifetime involvement with offending, arrests, and diversions and/or convictions. **Results:** At age 18-31, participants with a paediatric mTBI were significantly more likely than orthopaedic injury controls to endorse symptoms consistent with major depressive disorder by 3.17 times, anxiety disorders by 5.81 times, and internalising disorders in general by 5.80 times and the risk in the mTBI group was greater than that for those with moderate/severe TBI. Females with mTBI were significantly more likely than males, by five times, to endorse an internalising disorder. Paediatric mTBI was not significantly associated with externalising problems when compared with controls; however, males with mTBI were 6.57 times more likely to endorse externalising behaviours than females. **Conclusions:** Paediatric mTBI is a risk factor for internalising disorders in adulthood, particularly for females. Such findings have implications for assessment and treatment of problems associated with paediatric mTBI.

LIST OF ABBREVIATIONS

The following table describes the meaning of various abbreviations and acronyms used in the thesis.

Abbreviation	**Meaning**
ACC	Accident Compensation Corporation
ADHD	Attention-Deficit/Hyperactivity Disorder
CD	Conduct Disorder
CHI	Closed head injury
CIDI	Composite International Diagnostic Interview
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision
GAD	Generalised Anxiety Disorder
GABA	Gamma-aminobutyric acid
GCS	Glasgow Coma Scale
ICD-10	International Classification of Diseases, Tenth Revision
LOC	Loss of consciousness
MDD	Major Depressive Disorder
mTBI	Mild traumatic brain injury
OCD	Obsessive Compulsive Disorder
ODD	Oppositional Defiance Disorder
PTA	Post traumatic amnesia
PTSD	Post Traumatic Stress Disorder
SRDI	Self Report Delinquency Inventory
TBI	Traumatic brain injury

CHAPTER 1

INTRODUCTION

Traumatic brain injury (TBI) is a common type of accident amongst children and young adults up to the age of 25 years (McKinlay et al., 2008). It is also the most common cause of brain damage amongst this population and is a leading source of long-term disability and death worldwide (Feigin et al., 2013; McKinlay et al., 2008). Paediatric TBI has received increasing attention among researchers, as rates of TBI are higher among infants and young people than in the general adult population (Faul, Xu, Wald, & Coronado, 2010). More specifically, throughout the lifespan young people have the highest incidence of mild TBI (mTBI) (Guerrero, Thurman, & Sniezek, 2000). There is considerable variability in reported outcomes following paediatric mTBI. While some research suggests that the majority of individuals with mTBI recover without problems (Anderson, Heitger, & Macleod, 2006), there is mounting evidence that a proportion of those who experience paediatric mTBI will have long-term behavioural and psychiatric difficulties (Massagli et al., 2004; McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2009; Timonena et al., 2002).

A greater understanding of the long-term (i.e. five years or more) psychiatric and behavioural outcomes of paediatric mTBI will be beneficial for both affected individuals and those involved in their care. This review will examine the major problems associated with research in the field and then review literature on long-term psychiatric and behavioural outcomes associated with paediatric mTBI.

Definitions of Mild Traumatic Brain Injury

Various definitions, of what is referred to in this present study as mTBI, have contributed to a lack of agreement with regards to reported outcomes (Yeates & Taylor, 2005). For the purpose of this review of the literature, the words implemented in each study reviewed will be used and italicised.

Mild TBI traditionally incorporates the types of injuries implied by terms such as *minor, head trauma, closed head injury, brain injury,* and *head injury* (Wilde et al., 2012). Additionally, the term *concussion* is also often used interchangeably with the term mTBI. However, there is no consensus on the definition of concussion, or whether it is even different from mTBI. Anderson et al. (2006) define a *concussion* as an acute trauma-induced change of mental function, usually lasting less than 24 hours and the individual is expected to recover within 2–3 weeks. Symptoms are thus expected to spontaneously resolve within a limited time frame. The interchange between the two terms mTBI and concussion, neither of which is clearly defined, may help to explain why mTBI is not considered to have long-term consequences. As explained by Laker (2011), the use of different names for mTBI is a "culture" issue in which the sports community, favour the term *concussion*, whereas the general medical community prefers mTBI, conceivably because they will see the full spectrum of injury (mild, moderate, and severe), while a sports medicine provider is more likely to treat *concussions* or milder brain injuries.

This confusion over definition has filtered down into the public, whose knowledge about *concussions* and the different terminology associated with this type of injury was found to be largely inaccurate (McKinlay, Bishop, & Mclellan, 2011). Despite the lack of agreement over the definition of mTBI, there is a general agreement in the literature that a TBI occurs when a forceful movement of the head (with or without impact) results in transient alteration of mental status, such as confusion or disorientation, loss of memory, or brief loss of consciousness (Wilde et al., 2012).

Issues with paediatric mTBI conceptualisation. Further contributing to conceptual challenges is the fact that despite the relatively lower frequency of severe TBIs, there is greater agreement about how they should be defined when compared with mTBI. "This determination represents one of the most fundamental measurement and definition problems confronting researchers of *head injury* across the age span" (Satz et al., 1997, p. 126).

As explained by Satz et al. (1997) and Satz (2001), assessment of severity in the acute period of hospitalisation often examines alterations in consciousness, as assessed by the Glasgow Coma Scale (GCS); loss of consciousness (LOC); neurological status; and changes in orientation and memory, or post traumatic amnesia (PTA). The GCS is widely used, yet it has a number of limitations when applied to the paediatric population, as well as to those with mTBI. For instance, the verbal component of the GCS assumes comprehension of language (Wilde et al., 2012), which is not helpful when applied to infants and toddlers who are preverbal (Fletcher, Ewing-Cobbs, Francis, & Levin, 1995). Similarly, the assessment of PTA is of restricted use in the paediatric population as it is dependent on an orientation to time, place and person, but temporal orientation is not well developed in young children (Wilde et al., 2012).

Although these measures have been useful in defining more severe TBIs, patients with mTBI typically have transient symptoms of dizziness, headaches, confusion, and fatigue with no, or brief LOC of less than 20 minutes, no abnormal neurological signs and brief (if any) hospitalisation (Davis, 2012). This has meant that measures frequently rely on self-report of often confusing and vague experiences. Further, the GCS was not designed to distinguish among different types of mild TBI as many patients are oriented by the time they are first assessed and thus score at the top (or least severe) end of the GCS (Nell, Phil, Yates, & Kruger, 2000). Problematic, as the category *mild* includes different levels of severity, and may include both individuals who did and did not require hospitalisation and/or medical attention.

In this regard, research can often be criticised for not outlining upper and lower inclusion criteria for mTBI, and for being overly inclusive or exclusive of injuries (Kibby & Long, 1996). When defined, the upper and lower severity limits for mTBI have differed markedly amongst studies from a blow to the head through to the inclusion of some moderate or even severe cases in the mTBI category (McKinlay, Grace , Horwood , Fergusson , & MacFarlane 2010). It is a major source of confusion in the literature that the lower limits of mTBI tend to be vaguely defined, if at all. This lack of a lower limit exclusion criteria may lead to individuals being categorised as having mTBI despite

having minimal or no neurological damage (Kibby & Long, 1996). If participants whose injury would be too minor to meet criteria for mTBI are included in other studies, it confounds conclusions that can be drawn from the research.

In sum, severity is determined by diverse means of assessment and with varying severity cut-off points and will differ depending on the criteria used in each study. As such, the term *mild* is likely to have different meanings in different research.

Epidemiology

Definition of mTBI. Determining the epidemiology of mTBI is challenging for a number of reasons (Comstock & Logan, 2012). First, as discussed, the spectrum of mTBI rages from milder *concussions* to more severe mTBI and upper and lower limits of mTBI severity are not always made explicit in the literature. Thus, the prevalence of paediatric mTBI varies depending on how it is defined (McKinlay et al., 2008).

Incidence. Authors who reviewed literature on the incidence of hospital-treated patients with mTBI reported that the incidence of mTBI in children and adolescents generally varies between 100-300 per 100 000 per year, with 70-90% of all treated brain injuries classified as mild (Cassidy et al., 2004). Previous studies, such as those reviewed by Cassidy et al. (2004), tend to rely on hospital admission or discharge information to determine incidence, which is likely to drastically underestimate the true extent of the problem, as mTBI often does not result in hospital admission. Moreover, rates of paediatric hospitalisation for mTBI have decreased over the past 15 years (Bowman, Bird, Aitken, & Tilford, 2008) and the true population-based rate is probably much higher than expected from the numbers reflected by hospital records.

Certainly, two studies conducted in New Zealand found the incidence of all TBI cases (admitted to hospital or not) were much higher than those reported by studies based on hospital

records only. Recently, Feigin et al. (2013), calculated the total incidence of all TBIs in New Zealand as 790 cases per 100 000 people. The incidence of mTBI was 749 cases per 100 000, and moderate/severe TBI was 41 cases per 100 000 people. They reported that 95% of all TBI cases are mild, and the risk of acquiring mTBI was more than 18 times greater than the risk for moderate to severe TBI. Children, adolescents and young adults (aged 0-34 years) made up approximately 70% of all TBI cases. Of note, 36% percent of participants with TBI did not present to hospitals and were identified through accident and medical clinics, Accident Compensation Corporation (ACC), and other databases and self-referrals.

A prospective longitudinal study conducted in New Zealand by McKinlay et al. (2008) presented similar findings to Feign et al. (2013). Their reported incidences were also much larger (by approximately 10 times) than previously reported figures based on hospital records only, such as those reviewed by Cassidy et al. (2004). In the research conducted by McKinlay et al. (2008), cohort members were assessed at birth, four months, one year, and then annual at intervals up to 16 years of age and then again at 18, 21, and 25 years. During these assessments, comprehensive information was obtained on the child's history of all injuries leading to medical attention. Thus, unlike prior studies, this study was able to identify all individuals who had experienced a TBI, not just those for whom hospital records could be located. The researchers found the occurrence of TBI events in New Zealand, both hospitalised and non-hospitalised, ranged from 1000-3000 per 100 000 people per year, with an overall prevalence of approximately 30%. The average rate of injury was highest in children less than five years of age and between 15-20 years. Similar to the findings of Feign et al. (2013), McKinlay et al. (2008) reported that the majority of the TBIs were mild (approximately 90%).

Sex differences in incidence. A consistent finding in the literature is that TBI is approximately twice as common in males as in females across the ages (Feigin et al., 2013; Peloso, Von Holst, & Borg, 2004). Exposure to high risk activities, such as sport and recreational activities, rather than sex per se, may account for much of the observed differences between sexes (Comstock & Logan, 2012; Rivara, Bergman, LoGerfo, & Weiss, 1982).

Cause of injury. Feigin et al. (2013) reported that most TBI cases are due to falls (38%), mechanical forces (21%), transport accidents (20%), and assaults (17%). Falls were the main cause of TBI in young children (76%), whereas mechanical forces were most common in children aged 5–14 years (30%), and in adolescents and young adults aged 15-34 years (48%). Transport accidents accounted for most TBI cases in people aged 15–64 (25%). Male children, adolescents and young adults had a greater risk of TBI due to transport accidents and exposure to mechanical forces, and had a higher risk of TBI due to assaults than did females of the same age. Similarly, McKinlay, et al. (2008) found that in New Zealand, the most common source of injury for individuals aged 0-14 were falls and being hit by an object. Contact sports, assaults and motor vehicle accidents were the leading cause of TBI for 15-25 year olds.

Methodological Difficulties with Research on Paediatric mTBI

Our understanding of paediatric mTBI is still evolving and the existence of long-term outcomes following injury continues to be debated. As discussed, mixed outcomes following paediatric mTBI may be related to inconsistent terms and differing criteria used to describe mTBI in the literature, as well as inappropriate comparison groups, small sample sizes and a need for more longitudinal research (of five years or more). Moreover, the lack of standardised measures used in the mTBI literature makes repetition and comparison between studies challenging. Methodological issues discussed below include: sample issues, inappropriate comparison groups and the key criteria required to be a methodologically strong study.

Sample issues. Studies vary dramatically in terms of their sampling design. Amongst the research on psychiatric and behavioural consequences following paediatric mTBI, sample sizes tend to be relatively small and as a result are at times grouped with moderate TBI groups. This limits the conclusions that can be drawn for those with mTBI due to the great heterogeneity of these two different injury severities. Further, within the paediatric mTBI literature, samples used tend to under-

represent children who are younger than school age and also those in late adolescence, instead focusing on the years between.

Comparison groups. There is considerable variation with regard to control groups, particularly in older research, where many studies either did not use any control group or did not make use of an other-injured control group. As Wilde et al. (2012) explain, an appropriate control group is key in the study of mTBI. Without this, it could feasibly be argued that development of post-injury disturbances may reflect the emotional impact of a traumatic experience or injury rather than the consequences of the brain injury itself (Luis & Mittenberg, 2002). A more recent trend for studies to utilise an orthopaedic or other-injury comparison group has resulted from the need to control for variables confounding outcomes of TBI. These variables include the impact of a traumatic injury and pre-injury risk factors that may predispose individuals to injury (Basson et al., 1991; Stancin et al., 1998; Wilde et al., 2012).

Some research suggests that children who sustain traumatic injuries are more likely to display pre-injury psychiatric or behavioural difficulties, which may make it difficult to tease out the impact of pre-injury characteristics from outcomes of TBI (Wilde et al., 2012). For example, Max el at. (1997) note that high rates of psychopathology in TBI groups across studies may reflect the high pre-injury prevalence of psychiatric disorders in children who sustain a TBI. Indeed, youth with psychiatric disorders, particularly externalising problems, are more likely to engage in risky behaviour which may lead to a TBI. For example, Attention-Deficit/Hyperactivity Disorder (ADHD) has been associated with a propensity to sustain injury, including TBI (Gerring et al., 1998).

In contrast, the results of a prospective longitudinal study following a birth cohort, examined the behavioural effects associated with mTBI acquired during pre-school and controlled for a variety of pre-injury factors (McKinlay, Grace et al., 2010). The researchers found that pre-injury circumstances and characteristics were comparable across TBI and control groups and thus suggested that outcomes of mTBI may not just reflect the high pre-injury prevalence of psychiatric disorders in

children who sustain a TBI, but may be a result of injury to the brain itself. Unlike the study by Gerring et al. (1998), McKinlay, Grace, et al. (2010) prospectively collected information regarding pre-injury child and family characteristics and thus, were less likely to be affected by post-injury memory bias inherent to retrospective studies.

It seems that no single factor can account for the great variability in recovery patterns observed following paediatric TBI (Fletcher et al., 1995). It is likely that several mechanisms may act, both independently and interactively, to determine outcomes (Anderson, Morse, Catroppa, Haritou, & Rosenfeld, 2004). An orthopaedic injury comparison group controls for such factors that may not be controlled for by matching on demographic factors alone with a non-injured control group. It controls for the event of physical injury, hospitalisation, and family reactions to this, pre-injury behavioural problems, and socioeconomic factors that may be more common amongst children who experience accidents and injuries than those who do not. When conducting research on mTBI, a comparison group involving children who sustained a mild injury that did not involve the head and that resulted in acute medical care, is desirable (Yeates, 2010).

Criteria for a methodologically strong study. Satz (1997) identified key criteria, of which it was recommended that four out of six should be met in order for a study to be defined as methodologically strong. The six requirements include: 1) the presence of a control group (non-injured or other-injured); 2) longitudinal design with follow-up assessment; 3) clear definition of *mild head injury*, with no inclusion or pooling of more severe *head injuries*; 4) a sample size of greater than 20 participants; 5) standardised tests; 6) and control for pre-injury risk factors.

In a comprehensive review of the literature on mild *head injury* in children and adolescents Satz et al. (1997) concluded that 13 studies found adverse outcomes with regards to neuropsychological, academic, or psychosocial factors; 18 studies reported null outcomes and nine studies had indeterminate findings as there was no comparison group to contrast outcomes of mild *head injuries*. Informed by the six recommended criteria for a methodologically strong study, Satz

(1997) stated that the studies reporting null outcomes, as opposed to adverse outcomes, were more methodologically robust than those which reported adverse outcomes. The authors concluded that none of the studies finding adverse consequences were methodologically strong enough to warrant such conclusions. Many of these studies were flawed because of over-reliance on subjective reports, inadequate case definition, lack of control groups and lack of follow-up. The investigators thus favoured an acceptance of the null hypothesis– that *head injury* does not have adverse effects on psychosocial, neuropsychological or academic functioning. In a review of this original article, Satz (2001) again found that stronger studies more consistently reported null outcomes following mild *head injury*.

This criteria is however, not without limitations. For instance, Satz (1997) counted a follow-up of any length as longitudinal in design– this may be months to years post-injury. The studies addressing the outcomes of paediatric mTBI seldom have a longitudinal design of more than five years since TBI, and most fail to address the adult outcomes of paediatric mTBI. As such, the results may not be predictive of extended outcomes as childrens brains' have not yet reached full development and TBI sequelae are likely to be changing rather than static (Fletcher et al., 1995). Research on the long-term outcomes of paediatric mTBI tend to show that a long-term perspective of at least five years post-injury is required (McKinlay, Dalrymple-Alford, Horwood, & Fergusson, 2002; McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2010; Timonena et al., 2002). In addition to this, Satz (1997) required the presence of a control group (either non-injured or other-injured) in order for a study to be considered methodologically strong, yet as discussed, it has become increasingly apparent that an other-injured comparison group is advisable over a non-injured comparison group in order to control for pre-injury factors that may impact on outcome.

Factors Affecting Outcomes of Paediatric mTBI

Influence of sex on outcome. Our understanding of the outcome of paediatric mTBI is also hampered by the fact that the majority of research on TBI is conducted with male participants.

Furthermore, studies seldom separate sex in their analyses when considering the outcomes of TBI (Hirschberg, Weiss, & Zafonte, 2008). As will be seen, the word *sex* and *gender* are often used interchangeably in the literature, although the two are not synonymous. The word *sex* applies to differences in biological-make up, while the word *gender* applies to social and cultural interpretations of, and influences on, female and male identity (Delisi, 1996). For the purpose of this study, the differences in outcome between males and females will be described as sex differences.

Internalising disorders. Hirschberg et al. (2008), explain that while males and females are genetically quite similar, there are important structural and hormonal differences between the male and female brain, which is 'shaped' by hormones unique to each sex. Research in this area offers evidence of different serotonergic and dopaminergic neurotransmitter pathways in the female and male brain, something that may help to explain the different rates of psychiatric and behavioural difficulties between sexes. Research has demonstrated that females tend to have higher levels of serotonin in the brain compared with males, and males synthesise serotonin 52% faster than females. Serotonin levels have been implicated in various psychiatric and behavioural difficulties including depression, anxiety, and aggression and the noticeable disparity in serotonin between sexes may be a factor relevant to the lower incidence of unipolar depression in males compared with females (Nishizawa et al., 1997). Females also reportedly have a higher overall dopamine transporter density than males. The impact of differing amounts of 'dopaminergic tone' between sexes has been implicated in several neuropsychiatric conditions, such as schizophrenia and bipolar disorder (Hirschberg et al., 2008).

Females have also been noted to be more prone than males to anxiety disorders (Hirschberg et al., 2008) and it has been reported that females experience premenstrual and postpartum exacerbations of anxiety (Seeman, 1997). These are times of hormonal fluctuations, and it seems that females may become more anxious during relatively low levels of circulating oestrogen and progesterone. Oestrogens have been found to be gamma-aminobutyric acid (GABA) antagonists, leading to the

assertion that female hormones may promote an anxiolytic state and thus are possible contributors to the different rates of anxiety disorders between sexes (Seeman, 1997).

Externalising behaviours. Studies on prison populations tend to indicate that TBI has an influence on offending and externalising behaviours, particularly in males, and has an influence on violent behaviour in both sexes. For example, the rate of in-prison behavioural infractions (defined as a violation of the prisoner code of conduct, both violent and non-violent) was greater in inmates with TBI, predominantly mild in severity, over an 11.5-year period. For all infractions, male inmates with TBI had an increased rate of infractions by 32% and females had a non-significant increased rate of infractions by 8%. The increase appears greatest for inmates with violent infractions as both sexes had a significantly increased violent infraction rate, by 86% for males and by 144% for females (Shiroma, Pickelsimer et al., 2010).

A sex disparity in outcome is not specific to TBI. Sex differences in the expression of psychiatric difficulties such as ADHD have been reported. Following her review of the literature, Rucklidge (2008) reported that males with ADHD tend to be more disruptive, engage in more rule breaking behaviour and are more likely to have co-morbid disruptive behavioural disorders, while females are more likely to be diagnosed with the predominantly inattentive type of ADHD. Further, rates of depression and anxiety may be higher in females with ADHD, while physical aggression and other externalising behaviours may be higher in males with ADHD. Just as ADHD may be expressed differently between sexes, so may mTBI. As Hirschberg et al. (2008) point out, given the differences between sexes, it can be inferred that trauma to the brain may have sex-specific outcomes, which is important to be aware of for diagnosis and treatment.

Age at injury, age at testing, and duration since injury. When researching the long-term outcomes of paediatric mTBI there are other issues, aside from sex, of which researchers should be mindful of. Specifically, Taylor and Alden (1997) point out three important factors to be considered: age at injury, age at testing and duration since injury. The authors argue that the frequent confounding

of these three factors in studies of childhood *brain injury* create a major obstacle to our understanding of outcomes.

Age at injury. The effects of TBI sustained early in life tend to be regarded as distinct from the consequences of TBI acquired in adulthood (Anderson et al., 2009; Dagmara, Karmiloff-Smith, & Thomas, 2008; Taylor & Alden, 1997; Thompson et al., 1994). There is evidence to support the idea that outcomes of TBI differ significantly depending on the age it was acquired (Anderson et al., 2009). In adults, the concern is whether individuals return to premorbid levels of functioning, whereas in children the key issue is whether TBI interrupts on-going development and final level of skill attainment (Fletcher et al., 1995). Any measurement of outcomes in children must take into account change over time.

Key to the controversy surrounding age of injury and outcome is the debate summarised by Anderson, et al. (2009) as 'plasticity' versus 'early vulnerability'. Neuroplasticity implies that the brain is able to adapt and change in response to injury (Kolb, 1995). Explained by Anderson, et al. (2009), it is generally disputed whether the immature brain has a greater capacity for recovery than the adult brain. Plasticity was thought to be maximal early in development when the central nervous system is less rigidly specialised, and synapses and dendritic connections remain unspecified (Kennard, 1936). This flexibility allows for the reorganisation of functions from damaged areas of the brain to healthy tissue (Swain, 2006). It has therefore been argued that the developing brain is able to reorganise following injury, and that early *brain injury* produces milder outcomes than later *brain injury* (Anderson et al., 2009). There is, however, now mounting evidence to suggest the opposite.

Proponents of the early vulnerability model suggest that the young brain is uniquely sensitive to insult. There is now robust research demonstrating that younger age at the time of brain injury is an important risk factor for adverse immediate and long-term consequences (Taylor & Alden, 1997). Indeed, a long-term study that compared neuropsychological outcome 23 years after paediatric and adult TBI (predominantly mild; n = 119), concluded that children who sustain mTBI may be more

vulnerable to the development of chronic mild neuropsychological dysfunction than adults sustaining similar head injuries (Hessen, Nestvold, & Anderson, 2007). Younger age at injury may also be associated with more severe outcomes (Anderson, Catroppa, Haritou, Morse, & Rosenfeld, 2005; Fletcher et al., 1995; McKinlay, Grace et al., 2010; Thompson et al., 1994). This may be because cognitive development is dependent on the integrity of particular cerebral structures (Anderson et al., 2009; Hebb, 1942). Given the rapid neurodevelopment that occurs during childhood, any disruption has the potential to cause damage to brain structure and function.

As a general trend, injury at a younger age may result in more adverse outcomes; however, age at injury may not necessarily follow a linear correlation depending on the specific outcome measured. In terms of cognitive deficits, children acquiring a *brain injury* at younger ages tended to display greater cognitive deficits suggesting a linear association between age at insult and outcome (Anderson & Moore, 1995; Anderson et al., 2009). However, although it appears that younger age of TBI is associated with increased rates of some psychiatric disorders (McKinlay, Grace et al., 2010; Shoumitro, Lyons, Koutzoukis, Ali, & McCarthy, 1999), it seems that not all neuropsychological functions share the same linear pattern of vulnerability with respect to age at insult. Illustrating this, research into behavioural difficulties with children with a *brain injury* found that those who were injured between the ages of 7-9 years performed worse on behavioural measures than those with an early *brain injury* acquired at 3-6 years, and more like those with even younger insults (Anderson et al., 2009). A nonlinear pattern has also been found for depression but not anxiety, whereby the rate of depression, six months post-injury, for children injured after 12 years of age, was higher when compared with those injured before the age of nine years (Max et al., 2011). The finding may be a reflection of higher rates of depression found in adolescence compared with rates found in pre-adolescent youth (Carr, 2006). In contrast with depression, younger age at injury was associated with higher rates of new-onset anxiety, six months post-injury (Max et al., 2011). While younger age of TBI tends to be associated with more adverse outcomes, patterns remain somewhat unclear, and the impact of age at injury on outcome may differ depending on the sequelae being studied.

Critical stages of development. A non-linear relationship between age at injury and outcome is consistent with the theory of critical stages of development, a concept that proposes that early brain development follows a stepwise process consisting of periods of rapid growth and periods of relative stability. Interruption to these processes may have a significant impact on functioning (Crowe, Catroppa, Babl, Rosenfeld, & Anderson, 2012). Gronwall, Wrightson, and McGinn (1997) argue, that in adult populations, the pattern following *head injury* is of initial deficit that gradually recovers with time. In children, however, there may be no indication of deficit in the early days or weeks after injury, but various skills may fail to develop as quickly as in children who have not had a *head injury*. The study concluded that if injury occurs at an important developmental age, children may fail to develop relevant skills as quickly as non-*head injured* children.

Methodological issues with age at injury. There is little consensus in the literature of how different age groups should be conceptualised and categorised. Age of injury is an important variable and certainly the use of age categories is warranted if there is a reason to compare children above and below a pre-established age level. Despite this, researchers generally give little, if any explanation for categorising children into their various age groups. The wide variety of different age range groupings across studies make comparisons in outcome between studies challenging. Taylor and Alden (1990) suggest it may be preferable to conceptualise age as a continuous variable rather than arbitrarily create age group categories.

Duration since injury. The age of an individual when assessed and the length of time since their injury at the time of testing may also influence identifiable outcomes of TBI, yet such variables are not often discussed by researchers.

In terms of behavioural outcomes, the emergence or worsening of behavioural problems over time has been found in children who have sustained TBI early in life (Fletcher et al., 1995). A large-scale prospective study, using an unselected, general population birth cohort (N = 10 934) followed subjects up to 31 years of age. The vast majority (over 90%) of TBIs were described as *concussions*

and would likely be considered mTBIs. Data on TBI and mental disorders were collected from outpatient clinics of hospitals and from hospital discharge registers, further the Finnish Ministry of Justice provided information on criminal offenses for all participants. The average age when the TBI had occurred was between 9-10 years in males (mean age of injury for females was not described). It was found that TBI doubled the risk of developing mental disorders, but the mean ages at which psychiatric disorders were first identified tended to be between 22-26 years of age, over 12 years post-injury. Therefore, there may be a delay between age at injury and age at which psychiatric illness and/or criminal activity following TBI first becomes apparent (Timonena et al., 2002), in which case, longitudinal research on adult outcomes will be required in order to capture such consequences. This is especially so for individuals injured at a very young age, who would thus be unlikely to engage in criminal behaviour or display symptoms of psychiatric illness, such substance use disorders, until later in life. Giving further weight to the need for longitudinal research, in their article on the controversies and outcomes associated with paediatric mTBI, McKinlay (2010) stated that deficits following mTBI are consistently reported in studies that use a follow-up period of more than five years.

The Need for Longitudinal Research

Longitudinal research is essential in order to evaluate the outcomes of paediatric mTBI, as deficits may not become apparent until many years post-injury. More long-term research (five years or more) is required in order to obtain a fuller understanding of the outcomes of paediatric mTBI. While studies investigating the acute outcomes of mTBI are useful, they provide limited insight into the natural course of sequelae following paediatric mTBI.

Although symptoms following mTBI are at times considered to be time-limited, and certainly symptoms following a *concussion* are expected to resolve within two weeks of the injury (Yeates & Taylor, 2012), this is not always the case. When one considers the high base rate of *concussions*, even if only a limited proportion of individuals continue to experience long-term symptomology, this is a concern for a noteworthy number of individuals (Yeates & Taylor, 2012).

The key longitudinal studies that address the psychiatric and behavioural outcomes of paediatric mTBI are summarised in Table 1. Of the longitudinal studies, 9 out of 20 followed children and adolescents for more than five years post mTBI. More than half of the studies researching the psychiatric outcomes following paediatric mTBI reported adverse psychiatric or behavioural outcomes. Of these, adverse outcomes were reported in approximately 67% of studies with a longitudinal design of five years or more post-injury and approximately 73% of the studies with a follow-up of less than five years post-injury. These studies give evidence that paediatric mTBI may have both short and long-term psychiatric and behavioural outcomes.

Table 1.

Follow-up studies on psychiatric and behavioural outcomes of paediatric mTBI.

Author	Approximate length of assessment or follow-up post-injury	Findings
(Timonena et al., 2002)	0-31 years	Paediatric TBI (predominantly mild) increased the risk of developing mental disorders two-fold and was significantly related to later mental disorder with coexisting criminality in male cohort members.
(Koponena et al., 2006)	30 years	The authors reported that a risk of depression may be associated primarily with *milder* TBI.
(Klonoff, Clark, & Klonoff, 1993)	23 years	Mild *head injury* was significantly associated with psychological/psychiatric problems.
(McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2009)	9-16 years	Children who had been hospitalised for mTBI during preschool years were significantly more likely to demonstrate symptoms of ADHD, conduct disorder (CD)/oppositional defiance disorder (ODD), substance abuse, and mood disorder but not anxiety disorder in adolescence.
(McKinlay, Grace et al., 2010)	1-13 years	More severe pre-school mTBI (inpatient as opposed to outpatient) was associated with persistent negative effects in terms of psychosocial development.

(McKinlay et al., 2002)	1-13 years	Cases of confirmed mTBI were divided into either an outpatient or inpatient group. The inpatient but not the outpatient group displayed increased hyperactivity/inattention and CD between ages 10-13 years. Psychosocial deficits were more prevalent in the inpatient mTBI subgroup, injured before age 5.
(Max, Sharma, & Qurashi, 1997)	5 years	TBI, predominately mild, did not appear to be linked to psychiatric and behavioural sequelae as patients with a history of TBI (mild and moderate/severe grouped) were virtually indistinguishable from matched children without TBI five years post-injury.
(Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2008)	5 years	Severe TBI was associated with greater deficits than mTBI. Furthermore, behavioural outcomes were best predicted by pre-injury levels of functioning.
(Bijur, Haslum, & Golding, 1990a)	1-5 years	Children with mild *head injuries* were statistically indistinguishable from uninjured children on all outcomes except hyperactivity. The researchers concluded that mild *head injury* in school-aged children does not have an adverse effect on behaviour 1-5 years post-injury.
(Massagli et al., 2004)	3 years	Children with mTBI, with no prior psychiatric history, were at significantly increased risk for psychiatric illness, particularly hyperactivity, in the first year after injury. There was no evidence for an additional increase in risk in the three-year follow-up.

(Wetherington, Hooper, Keenan, Nocera, & Runyan, 2009)	1-3 years	After early TBI (mild, moderate and severe), preschoolers did not differ from one another or a matched comparison group in behavioural ratings.
(Hawley, 2003)	2.3 years	Behavioural problems, school problems, and anxiety were significantly more frequently reported by all TBI groups (mild, moderate and severe) than by controls. Most of these problems remained unresolved at follow-up.
(Brown, Chadwick, Shaffer, Rutter, & Traub, 1981)	2.25 years	The mild *head injury* group showed a raised level of behavioural disturbance before the accident but no increase thereafter. By contrast, there was a marked increase in psychiatric disorders following severe *head injury*.
(Asarnow, Satz, Light, Lewis, & Neumann, 1991)	2 years	Children with mild and children with severe *head injuries* had an excessive rate of behaviour problems.
(Max, Koele et al., 1998)	2 years	Severe TBI was associated with a significantly higher rate of current psychiatric disorders (63%) compared with children with mTBI (21%) and orthopaedic injury (4%).
(Bloom et al., 2001)	1 year	Findings demonstrated a high rate of psychiatric disorders following paediatric TBI (mild, moderate and severe). Depressive disorders and ADHD were the most common diagnoses. Children with internalising disorders tended to have *milder* injuries and a greater likelihood of symptom resolution over time than children with externalising disorders, who generally had more chronic psychiatric disorders.

(Light et al., 1998)	1 year	Mild *head injury* was not associated with increased probability of new, overt behavioural problems.
(Max et al., 2012)	6 months	Novel definite/subclinical depressive disorders at six month follow-up occurred in 11% of the children with TBI (mild, moderate and severe). No comparison to non-injured or other-injured groups was made.
(Luis & Mittenberg, 2002)	6 months	Results indicated that even milder forms of *brain injury* in children increase the risk for subsequent internalising psychiatric symptomatology (i.e., anxiety and depression).
(Max et al., 2011)	6 months	The findings suggested that younger children may be at greatest risk for developing novel anxiety disorder following TBI (mild to severe). No comparison to non-injured or other-injured groups was made.

While the relatively shorter-term outcomes of paediatric mTBI are important to understand, symptoms experienced in childhood may not be predictive of more extended outcomes and deficits may not become fully apparent for a number of years post-injury (McKinlay, Grace et al., 2010) and may not even become apparent until adulthood (Timonena et al., 2002). Thus, more longitudinal studies addressing the adult outcomes are required in order to identify if there are consequences of paediatric mTBI, especially for younger individuals (i.e. preschoolers) whose symptom presentation at six months post-injury is likely to be very different to symptoms experienced in adolescence or adulthood. Research addressing the long-term (five or more years post-injury), or the adult outcomes of mTBI, will help control for the possibly changing nature of post-TBI symptomology.

Overview of Psychiatric and Behavioural Outcomes of TBI

Children who survive a TBI may exhibit emotional, behavioural and psychiatric disorders in the months and years following their injury (Max, Koele et al., 1998; Max et al., 1999; Peloso et al., 2004; Taylor, Wade, Yeates, Drotar, & Minich, 2002; Taylor & Wisniewski, 2010). Whilst TBI has generally been found to be a risk factor in the development of psychiatric disorders (Bloom et al., 2001; Timonena et al., 2002), particularly following severe TBI (Max, Koele et al., 1998; Peloso et al., 2004), what is less well known is whether this link exists between paediatric mTBI and psychiatric illness and/or adverse behavioural outcomes. It remains a controversial issue, with studies reporting varied results (Oddy, 1993; Satz et al., 1997).

Of the psychiatric and behavioural issues researched, depression (Kirkwood et al., 2000b; Luis & Mittenberg, 2002), anxiety disorders (Asarnow et al., 1991; Hawley, 2003; Luis & Mittenberg, 2002), behaviour problems (Asarnow et al., 1991; Hawley, 2003), such as aggressive, oppositional, conduct disordered and antisocial behaviour (Max, Koele et al., 1998; McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2009a; Taylor & Wisniewski, 2010) and substance abuse (McKinlay et al., 2009) have been reported following paediatric mTBI.

Psychiatric outcomes. Longitudinal data tends to indicate that there may be ongoing psychiatric consequences for a proportion of individuals who sustain paediatric mTBI. For example, in a prospective study conducted by McKinlay et al. (2009), yearly information was obtained from participants aged 7-13 years. The researchers found that children who had been hospitalised for mTBI (n=76) prior to the age of five were significantly more likely to show symptoms of ADHD, CD/ODD, substance abuse, and mood disorder but not anxiety disorder in their adolescent years. The strengths of the study included non-mTBI controls, use of standardised measures, multiple assessments and large sample of mTBI cases.

Consequences extending into adulthood have also been reported. For example, in an earlier study with a longitudinal design of 23 years by Klonoff et al. (1993), emotional, cognitive and physical outcomes were reported by those who sustained a TBI (consisting of approximately 90% mTBI) in childhood. More recently, a large-scale prospective study by Timonena et al. (2002), with a birth cohort (N=10 934) followed participants from in utero and up to 32 years of age and found that mild to severe TBI during childhood and adolescence (up to 15 years of age) doubled the risk of developing mental disorders in adulthood. Paediatric TBI was also significantly related to later criminality in male cohort members. Conclusions from this study are however limited by the fact that different TBI severities were grouped together, length of unconsciousness due to a TBI was unknown and no neuroimaging examinations were carried out in the acute stage of injury.

Others have not found evidence that paediatric mTBI is linked with psychiatric difficulties. For example, Max, Koele, et al. (1998) found no link with paediatric mTBI (age at injury ranged between 5-14 years) and psychiatric difficulty two years post-injury. Conclusion from this study, are however limited by the relatively small sample size (n mTBI=24). Further, although the mTBI group did not significantly differ from controls two years post-TBI in terms of psychiatric presentation, research has shown that psychiatric illness may only manifest several years post-injury and often after 20 years of age (Timonena et al., 2002). Likewise, Max, Sharma et al. (1997) reported that in a child psychiatry inpatient unit, TBI (predominantly mild) (n=56) was not associated with increased rates of psychiatric disorders five years post-injury. However, the mean age of assessment was approximately 10 years of age and the expression of psychiatric illness may not be apparent at this young age. Thus a longitudinal perspective of greater duration would be useful.

Major depressive disorder. Results from research on the incidence of major depressive disorder (MDD) following paediatric TBI are somewhat varied. Whether or not mTBI is associated with increased rates of depression in children and adolescents remains a topic of debate, with some researchers concluding that more severe TBI is associated with increased depressive symptoms while

others have found that depression may be more common following mTBI when compared to more severe injuries (Kirkwood et al., 2000; Max et al., 2012).

In terms of relatively short-term outcomes, i.e. six months post-injury, Max et al. (2012) noted in their prospective study that new-onset depressive symptoms may develop following mTBI in children who were on average 10 years old (N =177). There is also evidence that paediatric mTBI increases the risk for subsequent internalising psychiatric symptomatology such as anxiety and depressions six months post-injury (Luis & Mittenberg, 2002). Increased rates of depression have also been reported following more severe paediatric TBI. A retrospective psychiatric interview with individuals with severe TBI found that one third of the children had a depressive disorder at some point after the injury (Fletcher et al., 1996). Bloom et al. (1993) utilised structured psychiatric interviews and reported depressive disorders in approximately one quarter of children who sustained a TBI between the ages of 6-15 years (mild, moderate, and severe grouped) (n=46). Overall, it seems that rates of depression may be elevated in individuals who sustained a TBI regardless of injury severity (mild, moderate or severe) when compared with controls. For example, a prospective study found that moderate to severe TBI in childhood increased the risk of depressive symptoms regardless of severity (Kirkwood et al., 2000). It is important to identify treatable co-morbidities resulting from TBI in order to improve functional outcome post-injury. For example, in adults with mTBI, successful treatment of depression resulted in significant alleviation of cognitive impairment (Fann, Uomoto, & Katon, 2001)

The findings of Cooper-Evans, Alderman, Knight, and Oddy (2008) may help to explain this. It was reported in this study that individuals with severe *acquired brain injury* who were functioning at a higher cognitive level and thus had more intact awareness of deficits, reported lower levels of self-esteem. In light of this, greater insight into loss of functioning in those with mTBI, compared to those with moderate/severe TBI may be a risk factor in the development of MDD.

Anxiety disorders. Anxiety is frequently linked with depression. In the largest prospective psychiatric interview of paediatric TBI (mild to severe TBI; N=177), novel depressive symptomology occurred in 11% of the children and of those children, 40% developed co-morbid novel anxiety symptoms at six month follow-up (Max et al., 2012). This rate of co-morbidity is not surprising as high co-morbidity between depression and anxiety is typical in the general population (Moffitt et al., 2007). While often co-occurring with depression, literature suggests rates of anxiety itself may be increased following TBI (Max et al., 2011). When anxiety symptoms or disorders develop after TBI, they are varied and may include Post Traumatic Stress Disorder (PTSD) (Luis & Mittenberg, 2002), phobic disorders (Vasa et al., 2002), Obsessive Compulsive Disorder (OCD) (Grados et al., 2008), and Generalised Anxiety Disorder (GAD) (Vasa et al., 2002).

Research suggests that paediatric mTBI increases the risk for subsequent internalising psychiatric symptomatology. Luis and Mittenberg (2002) found that rates of new onset of MDD and anxiety disorders were similar in paediatric mTBI groups (n = 42), aged 6-15 years, to the moderate/severe TBI groups (n=19) and these were significantly higher than in the orthopaedic group (n=35) six months post-injury. Disorders included specific phobia, panic attack, agoraphobia, GAD, PTSD, and MDD. It is important to note that the mTBI participants in Luis and Mittenberg's study were admitted for an overnight hospital stay, and given the low rate of hospitalisation in the mTBI population, participants in the mTBI group were likely in the upper severity for the *mild* category. Supporting Luis and Mittenberg's finding, Hawley, (2003) concluded that approximately two years post-injury, children aged 5-15 years at time of injury (mild and moderate/severe TBI, N=97) were significantly more anxious than healthy controls. Again, those with mTBI had been admitted to hospital for at least 24 hours and will likely be at the more severe end of the mild spectrum.

Contrary to the above studies, in a longitudinal prospective study by McKinlay et al. (2009), children from a birth cohort (initial N=1265) were assigned to one of three groups, either inpatient, outpatient or a reference control group. At age 14-16, children who had been hospitalised for mTBI were more likely to endorse MDD but not anxiety disorders.

Behavioural outcomes. McKinlay et al. (2009) explain that given the relative vulnerability of the frontal lobe to damage after the acceleration-deceleration force frequently involved in TBI, it should not be surprising that behavioural change is a reported outcome post-injury. The frontal systems are involved in capabilities such as impulse control and consideration of consequences. In turn, dysfunction of this area has been linked with violent, antisocial, criminal behaviour, and an increased risk of impulsive aggression (Brower & Price, 2001; Williams et al., 2010). It is thus not surprising that behavioural problems such as aggression (Cole et al., 2008), oppositional behaviour/conduct disordered behaviour (Asarnow et al., 1991; Max, Castillo et al., 1998; Moffitt et al., 2007; Teasdale & Engberg, 2001) and substance abuse (Moffitt et al., 2007) have been found to be more prevalent following paediatric TBI (Max et al., 2011; Max, Koele et al., 1998; Taylor et al., 2002).

Offending and disordered behaviour. Researchers have reported behavioural outcomes followig paedatric mTBI both in childhood and in adulthood. McKinlay et al. (2009), found that more severe instances of mTBI acquired during preschool years and under the age of five were associed with increased rates of CD, ODD, and substance abuse at age 14-16 years compared with non-injured controls (initial N=1265). Max, Castillo et al. (1998) conducted a prospective study that utilised standardised measures of oppositional and defiant behaviour amongst children aged 6-14 years, hospitalised after TBI. They noted that increased severity of TBI predicted ODD symptomatology two years post-injury, and prior to that, the influence of psychosocial factors appeared to better account for ODD symptomatology. Further, Catroppa et al. (2008) offered evidence that increasing TBI severity (n mTBI=11, n moderate TBI=22, n severe TBI=15) was associated with increased behavioural difficulties five years post-injury in a paediatric sample compared with healthy controls (n=17).

In terms of adult outcomes, Timonena et al. (2002) made use of a large birth cohort reported that TBI acquired during childhood and early adolescence elevated the risk of criminal offending among mentally disordered cohort males during the adult years but was not significantly associated with later heavy alcohol use. However, some have argued that a history of pre-injury aggression and

attention difficulties seem to place children at-risk for demonstrating aggressive behaviour post-TBI (Max, Koele et al., 1998). Moreover, ADHD in itself has been found to be associated with a variety of psychiatric disorders including substance abuse and/or dependences, antisocial and criminal behaviour (Schilling, Walsh, & Yun, 2011) and there may be multiple links, that is, circular causality, between ADHD, substance use, criminality and TBI (Timonena, et al., 2002).

Traumatic brain injury has been associated with offending behaviours. Rates of TBI tend to be elevated in prison populations when compared with the general population. A meta-analysis estimated the prevalence of TBI in offender populations at 60% (Shiroma, Ferguson, & Pickelsimer, 2010). Researchers have also found in a prison-based sample that of the 60% of prisoners who reported *head injuries*, 48% had experienced mTBI and 16% moderate/severe TBI (Williams et al., 2010). Further, greater frequency of self-reported TBI was associated with greater number of convictions in a study (N=197) by Williams, Cordan, Mewse, Tonks, and Burgess (2010). In particular, three or more self-reported TBIs were associated with violent offences and those with self-reported TBI also reported greater mental health problems and misuse of cannabis. Limitations to this study were no comparison group and a reliance on retrospective self-report (Williams et al., 2010). It has also been found that adolescents with TBI had committed both violent and non-violent crimes significantly more often than adolescents without TBI (Luukkainen, Riala, Laukkanen, Hakko, & Rasanen, 2012). Leon-Carrion and Ramos (2003) showed how a history of paediatric TBI was linked with violent offending in adulthood, and what differentiated the violent from the non-violent group of prisoners was a history of untreated *head injury,* highlighting the need to identify and treat at-risk youths.

Other researchers have reported no behavioural outcomes following mTBI. For example Crowe, Catroppa, Franz and Anderson (2012) compared the behavioural functioning of children who sustained mTBI (n = 20) before three years of age with a group of uninjured children (n=27). No significant differences were found on parent behaviour ratings between groups at approximately 40

months post-injury. However, outcomes were measured 40 months post injury and behavioural disparities between the groups may only appear as the children grow older.

A longitudinal study by Bijur et al. (1990), utilised a non-injured and other-injured control group and did not find that mild *head injury* (n=114) had an impact on aggressive behaviour in children injured between the ages of 5-10, at 1-5 years post-injury. Further, when compared to children with other types of injuries, the non-injured control group scored similarly on measures of aggression as the children with mild *head injuries*. However, a limitation of Bijur et al.'s study was that it made use of children, whose *head injuries* were in the milder range of mTBI and this may confound the reported lack of outcomes. Another weakness of the Bijur et al. (1990) study was that it required parents to recall information about their child's injury up to five years post-injury and the information obtained may not be as accurate as that obtained from prospective studies.

Similarly to the Bijur et al. (1990) study, in one of the larger studies on paediatric mTBI in children aged 8-16 years (n=119), the behavioural functioning of children with mild *closed head injury* (CHI) did not differ significantly from the other-injury control group one year post-injury (Light et al., 1998). Before their injuries, both the *head injury* and other-injury groups had increased behavioural difficulties, relative to the non-injured group (highlighting the importance of an other-injured comparison group). The researchers concluded that head injury of the *mildest type* was not associated with the development of behavioural difficulties one year post-injury. This prospective study, designed to overcome major methodological problems with research in the field, made use of two control groups (non-injured and other-injured) and ensured careful control of pre-injury factors, however, outcomes are not likely to be static and may be different several years post-injury.

There is thus much variability in reported outcomes on behavioural difficulties following paediatric mTBI and more research is needed in order for us to obtain a fuller understanding of the consequences, both short- and long-term.

Summary

Despite a growing body of research in the area, the psychiatric and behavioural outcomes of the most prevalent form of paediatric TBI, namely mTBI, remain imperfectly understood. The range of studies using standardised measures that reported on psychiatric disorders following paediatric mTBI is small, but generally indicate that children with a mTBI have increased rates of psychiatric disorders and behavioural problems compared with other-injured or non-injured controls, although these differences are not always statistically significant (Brown et al., 1981;Comstock & Logan, 2012; Luis & Mittenberg, 2002; Max, Koele et al., 1998). These somewhat unpredictable outcomes after paediatric mTBI restrict health professionals in their ability to identify children at high risk for adverse outcomes who may need a more thorough follow-up (Max et al., 2011).

The debate continues as to whether paediatric mTBI does in fact result in long-term psychiatric or behavioural problems. However, as Yeates and Taylor (2005) point out, with mTBI being the most common form of TBI, even if only a small proportion of children and adolescents suffer enduring negative outcomes, then mTBI is a serious public health concern. Cooper-Evans, et al. (2008) explain that a better understanding of such outcomes could have important implications for rehabilitation, adjustment and quality of life and is necessary in order to enhance our understanding of which children are at-risk, the type of risks they face, and how to optimise their recovery following *brain injury* (Taylor & Alden, 1997).

The Current Study

Objectives. Given the need for more research on the long-term outcomes (i.e. five years or more) of paediatric mTBI, the goals of the current study are to:

1. Examine the relationship between mTBI and the development of internalising disorders (including MDD and anxiety disorders) and externalising problems (including offending behaviour; arrests; diversions and/or convictions; and substance abuse and/or dependence), whilst utilising a design that addresses previous methodological limitations (i.e.a longitudinal design; standardised instruments; and two control groups).
2. Compare rates of internalising and externalising problems between sexes.
3. Determine the impact of age at injury and duration since injury on outcome.

Hypotheses. Based on previous research it was hypothesised that:

1. The consistent with a dose-response effect, highest rates of psychiatric illness including MDD, anxiety disorders and internalising disorders in general, will be found in the moderate/severe TBI group, followed by the mTBI group, with the lowest rates in the orthopaedic injury group.
2. The highest incidence of behavioural difficulties, including offending, arrests, diversions and/or convictions, substance abuse and/or dependence and externalising behaviours in general will be in the moderate/severe injury group, followed by the mTBI group, with the lowest rates in the orthopaedic injury group.
3. Females will be at greater risk of internalising disorders including MDD and anxiety disorders, while males will be at greater risk of externalising behaviours including offending, arrests, diversions and/or convictions, and substance abuse and/or dependence.
4. Younger age of TBI will be associated with increased rates of psychiatric and behavioural difficulties (Bowman et al., 2008; Moffitt et al., 2007; Teasdale & Engberg, 2001).
5. The extent of these problems will become increasingly apparent as the number of years post-injury increases (McKinlay, 2010; Timonena et al., 2002).

Strengths of study. Our understanding of psychiatric outcomes following paediatric mTBI is hampered by a number of factors and the long-term consequences of mTBI in infants and very young children have not been well documented (Carroll, Cassidy, Holm, Kraus, & Victor, 2004). Relatively few studies have assessed the impact of paediatric TBI on psychiatric and behavioural difficulties in adulthood. While the cognitive impairments of TBI have been extensively studied, less understood is the personal and social difficulties, which may have the most far-reaching consequences (Lezak, Howieson, & Loring, 2004). This study will contribute to the existing research by offering a longitudinal perspective (of five or more years post-injury) and will evaluate the adult psychiatric and behavioural outcomes of paediatric mTBI.

Distinct features of this research include the ascertainment of a mTBI sample from a cohort who were injured between the ages of 1-17 years and a longitudinal design following children from 5-26 years post-injury, with all participants being over 18 years of age at the time of assessment. This study will also contribute to our knowledge regarding the impact of sex on the expression of difficulties post-TBI. Additionally, the use of two comparison groups, a moderate/severe TBI group and an orthopaedic injury group is ideal as it helps control for any pre-injury behaviour that may have increased the risk for traumatic injury in the first place, and hence may impact on outcomes.

The study meets all of the six key criteria identified by Satz (1997) including 1) the presence of a control group (non-injured or other-injured); 2) longitudinal design; 3) clear definition of mild *head injury*, with no pooling with more severe head injuries; 4) sample size greater than 20 participants; 5) standardised tests and 6) control for pre-injury risk factors. Thus, the present study is in a unique position to advance scientific knowledge about the long-term, adult psychiatric and behavioural outcomes of paediatric mTBI.

CHAPTER 2

METHODOLOGY

Research Design

The study involved a within group design, and participants were categorised into one of three groups based on their injury characteristics: mTBI, moderate/severe TBI or orthopaedic injury. The prevalence of MDD, anxiety disorder, internalising disorders in general, offending behaviour, arrests, diversions and/or convictions, substance abuse and/or dependence and externalising behaviours in general following paediatric mTBI were examined using data drawn from a prospective longitudinal study.

Sampling Procedure and Participant Characteristics

This study was approved by the Upper South New Zealand Regional Ethics Committee as shown in Appendix A, and informed consent was given by all participants. Appendices B-D shows the information sheets, reply slip and consent form given to participants.

Participants were recruited via an audit of the neurosurgeon's historical files, an audit of hospital emergency department and admission records, and from community notices, which included advertisements on buses, mall notice boards and notices around the University of Canterbury. Information regarding injury severity was collected using a file review.

Inclusion criteria. General inclusion criteria for the study were that each participant had experienced an injury event (TBI or orthopedic injury) as a child, aged 0-17 years, were now 18 years or older. It was required that had been a duration of at least five years post-injury at the time of participation in the study. In this current study, the term pediatric thus encompasses one year of age,

up to and including 17 years of age, which follows the typical age span of children prior to and including their final year of schooling (School Education, n.d). All participants were fluent in English, as assessed by the examiner at point of initial contact, and were able to understand and answer the questions.

Mild TBI inclusion criteria. Equivalent numbers of individuals who had experienced mTBI were recruited from an audit of medical records (n=51, 29% response rate) or from community notices (n=10). Participants were included in the mTBI group if they met the following criteria: 1) a medically confirmed diagnosis of mTBI; 2) LOC of less than 20 minutes; 3) PTA of less than one hour; 4) GCS score of 13-15; 5) a hospital stay less than 48 hours due to the brain injury only, not because of other physical injuries; and 6) no evidence of skull fracture or lesion on tomography. Mild TBI was defined according to the recommendations of the World Health Organisation (Carroll et al., 2004). A total of 62 participants with mTBI were recruited. In the mTBI group, falls were the most common mode of injury (n=38) followed by running into an object (n=9), being hit by an object (n=5), playing sport (n=4), car accident (n=3), hit by car (n=2) or assault (n=1). Due to missing data (n=5), the information from a total of 57 mTBI subjects (n=27 females), aged 18-30 years (M = 21.86, SD = 2.86) was analysed.

Moderate/severe TBI inclusion criteria. The inclusion criteria for the moderate/severe TBI control group involved: 1) a clinical diagnosis of moderate or severe TBI, 2) skull fracture, evidence of lesion on tomography, and 3) cerebral haemorrhage or PTA greater than 24 hours. More specifically, the criteria for moderate TBI was: 1) GCS of 9-12 or higher if accompanied by radiological abnormalities; 2) PTA less than one week; and 3) less than six hours LOC. Criteria for severe TBI included: 1) PTA greater than one week; 2) LOC for more than six hours; and 3) GCS less than 9. The audit of hospital records identified 271 individuals that met the inclusion criteria for a moderate/severe TBI. Subsequent exclusions were made due to the following reasons: 1) no current contact information (n=49); 2) no longer living in the greater Christchurch region (n=29); 3) deceased

(n=11) or iv) injury severity prevented testing (n=7). Of the individuals who were able to be contacted 59 agreed to participate (33%). A further six individuals who met the inclusion criteria were identified through community notices. A total of 62 participants with moderate/severe TBI were recruited (n=22 females), aged 18-31 years (*M* = 23.15, *SD* =3.52). Participants in this group experienced coma for 1-24 hours (n=12), 1-7 days (n=8); subdural/subarachnoid cerebral haemorrhage (n=6); skull fractures/contusions (n=32); or experienced PTA longer than 24 hours (4). The mode of injury varied: hit by car (n=10); fall (n=31); car accident (n=12); assault with blunt object (n=2); hit by a falling object (n=3); sport (n=2); and unknown (n=2).

Orthopaedic injury inclusion criteria. An orthopaedic comparison group was used to control for factors that may be associated with children who experienced injuries in general. Participants were recruited from an audit of hospital records (n=29, 25% response rate) and from community notices (n=14). Participants in the control group were excluded if they had experienced a TBI. Due to missing data (n=1), the information from a total of 42 orthopaedic control subjects (n=25 females), aged 18-30 years (M = 21.86, SD = 3.39) who had sustained a fractured limb as a child was analysed (Table 2 and Table 3).

Table 2

Years post-injury, Age at Injury, Age at Testing and Number of Years Post-injury Per Injury Group.

	N	Range	M(SD)
Moderate/severe TBI	62		
Age at injury		1-17	10.95(4.93)
Age at testing		18-31	23.15 (3.52)
Years post-injury		5-26	11.97 (5.35)
Mild TBI	57		
Age at injury		2 - 17	10.43 (4.05)
Age at testing		18-30	21.86 (2.86)
Years post-injury		5 - 25	11.12 (4.78)
Orthopaedic injury	42		
Age at injury		3-17	10.43 (3.83)
Age at testing		18 - 30	21.86 (3.39)
Years post-injury		5 - 22	11.12 (4.28)
Total	161		

Table 3 shows the sex differences between the three injury groups. There were a greater number of male participants in the moderate/severe TBI group and in the mTBI group and more female participants in the orthopaedic injury group. The difference in the rates of occurrence between sexes was significant (X^2=6.28, p=0.04).

Table 3

Amount of Participants per Injury Group, According to Sex.

	Moderate/Severe TBI n (%)	Mild TBI n (%)	Orthopaedic Injury n (%)	Total	X^2	*p*
N	62	57	42	161		
n female	22 (35.5%)	27 (47.4%)	25 (59.5%)		5.90* [a]	.052
n male	40 (64.5%)	30 (52.6%)	17 (40.5%)			

Note. X^2 = Pearson Chi-Square; [a] X^2 for sex; * $p \leq .05$.

Sample Size, Power and Precision

The disorders in this study generally range from 10-30% population prevalence. A statistical power of 0.8 was desired with a minimum detectable odds ratio of three. These parameters gave a required sample size between 126 and 213. The gathered sample fell within this range and is considered sufficient for this analysis.

Measures and Procedure

Each participant was asked to attend a three hour assessment conducted at the University of Canterbury, New Zealand. The Composite International Diagnostic Interview (CIDI) is a series of structured interviews designed to assess mental disorders according to the International Classification of Diseases, Tenth Revision (ICD-10) and DSM-IV (The World Mental Health Composite International Diagnostic Interview, n.d). The CIDI was conducted by a post doctoral researcher, skilled in neuropsychological testing. Participants' lifetime experience of symptoms consistent with MDD, anxiety disorders (including GAD, panic attacks and panic disorder, agoraphobia, social phobia, PTSD and specific phobia), and substance abuse and/or dependence were assessed. Self-

reported offending data was collected using the Self Report Delinquency Inventory (SRDI) (Elliott & Huizinga, 1989), whereby participants' were also asked to report on their lifetime involvement with offending, arrests, and diversions and/or convictions.

Major depressive disorder was used as a measure of mood difficulty because of its relatively high prevalence compared with other mood difficulties. Of the anxiety disorders, panic disorder (with or without agoraphobia), panic attacks, social phobia, specific phobia, PTSD, and GAD were grouped under the umbrella of anxiety disorders. The anxiety disorders were grouped due to the relatively low base rate of these individual disorders and limited sample size when participants were split into the three different injury groups. Finally, offending behaviours, arrests, diversions and/or convictions, and substance abuse and/or dependence were included to assess externalising problems.

Reliability and validity. Both the CIDI and the SRDI are considered to have acceptable reliability and validity. Diagnoses made by the CIDI were found to be significantly related to independent clinical diagnoses, however, there was some lack of individual-level concordance, likely due to the relative unreliability of clinical interviews, and the literature shows that test-retest reliability is higher for diagnostic classifications based on CIDI interviews than for semi-structured clinical interviews (Kessler & Ustun, 2004). Further, a number of studies reviewed by Thornberry and Krohn (2009) assessed the reliability of self-reported delinquency measures, such as the SRDI. In general, the results of these studies indicate that these measures are acceptably reliable. A threat to validity, however, is that, although the majority of all offenses are reported, there is still substantial underreporting. The authors nonetheless concluded that despite this challenge, the technique seems capable of producing both valid and reliable data (Thornberry & Krohn, 2009).

Major depressive disorder. Each participant was assessed as to whether they had ever experienced symptoms consistent with the diagnosis of MDD. A summary variable "MDD ever" was constructed was and coded 0=no and 1=yes according to whether participants met criteria for MDD.

Anxiety disorders. Participants were asked to identify whether they had experienced symptoms consistent with a diagnosis of one or more of the following anxiety disorders: panic disorder (with or without agoraphobia), panic attacks, social phobia, specific phobia, PTSD, or GAD. A summary variable "anxiety ever" was constructed was and was coded 0=no and 1=yes, depending on whether a participant met criteria for one or more anxiety disorders.

Internalising disorders. In addition to the variables "MDD ever" and "anxiety ever", the variable "internalising disorders" was created. An internalising disorder was coded based on at least one experience with symptoms consistent with MDD and/or an anxiety disorder. The variable was either coded 0=no or 1=yes according to this.

Substance abuse and/or dependence. Participants were also asked to identify whether they had ever met criteria for alcohol and/or other substance abuse and/or dependence. A summary variable "drug and alcohol" was created was coded 0=no and 1=yes.

Offending behaviours. Each participant was assessed as to whether they had ever had experiences such as assaulting another person, drunk and disorderly behaviour, being arrested, having a diversion and/or conviction, received fines (excluding motor vehicle fines), and had involvement in petty crime (theft, vandalism, or ever sold drugs). A summary variable "offending history" was created was and was coded 0=no and 1=yes.

Arrests, diversions and/or convictions. In addition to the variable "offending history," separate variables were created according to whether participants' endorsed ever having had one or more: "arrests," or "diversions and convictions". Summary variables were coded 0=no and 1=yes.

Externalising behaviours. Externalising behaviour was defined as the presence of offending behaviour, including arrests, diversions and/or convictions, and also substance abuse and/or dependence. The variable was coded 0=no or 1=yes according to the presence or absence of one or more of these externalising behaviours.

Statistical Analysis

The literature tends to indicate that factors such as sex, age at injury and length of follow-up post-injury have an influence on outcomes (Hirschberg et al., 2008; Taylor & Alden, 1997). It seems that younger age at injury may be associated with more adverse outcomes (Taylor & Alden, 1997) . Additionally, though relatively few studies report on the sex distribution in terms of the likelihood of difficulties post-TBI, according to the DSM-IV-TR (2000), females in the general population are at significantly greater risk than males to develop depression and anxiety (Carr & McNulty, 2006). Conversely to this, males seem to be at greater risk of externalising behaviours than females in the general population (Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, Text Revision, 2000). It is for these reasons that sex, age at injury and duration since injury were included as covariates in the analyses of the data.

Differences between groups in terms of age at injury, number of years post-injury, age at testing and sex) were assessed using descriptive statistics. Comparisons of the various internalising disorders and externalising behaviours were assessed using binary logistic regression, generated by comparing the TBI groups to the orthopaedic injury group. The risk of various internalising disorders and externalising behaviours was evaluated according to age at injury, duration post-injury and the age at time of assessment. The groups were then spilt and the risk of each problem was assessed in each injury group according to sex.

CHAPTER 3

RESULTS

Major depressive disorder. Overall 41.6% of all participants endorsed having had symptoms consistent with MDD; 40.3% of participants in the moderate/severe TBI group, 52.6% of the mTBI group and 28.6% of the orthopaedic injury group. The difference between the injury groups were significant ($p \leq .05$). When sex was considered, 59.1% of females compared with 30% of males in the moderate/severe TBI group; 63% of females compared with 43.3% of males in the mTBI group; and 36% of females compared with 17.6% of males in the orthopaedic injury group reported symptoms consistent with MDD. These sex differences were significant in the moderate/severe TBI group but not the mTBI or orthopaedic injury group (Table 4 and Figure 1).

Table 4

Amount of Female and Male Participants per Injury Group who Endorsed Symptoms Consistent with Major Depressive Disorder

	Total N	N endorsed (%) [a]	X^2	*p*
Major Depressive Disorder				
Moderate/Severe TBI	62	25 (40.3%)*	5.00	.025
Female	22	13 (59.1%)*		
Male	40	12 (30%)*		
Mild TBI	57	30 (52.6%)*	2.20	.138
Female	27	17 (63%)		
Male	30	13 (43.3%)		
Orthopaedic injury	42	12 (28.6%)*	1.67	.196
Female	25	9 (36%)		
Male	17	3 (17.6%)		
Total	161	67 (41.6%)*	5.83	.054

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

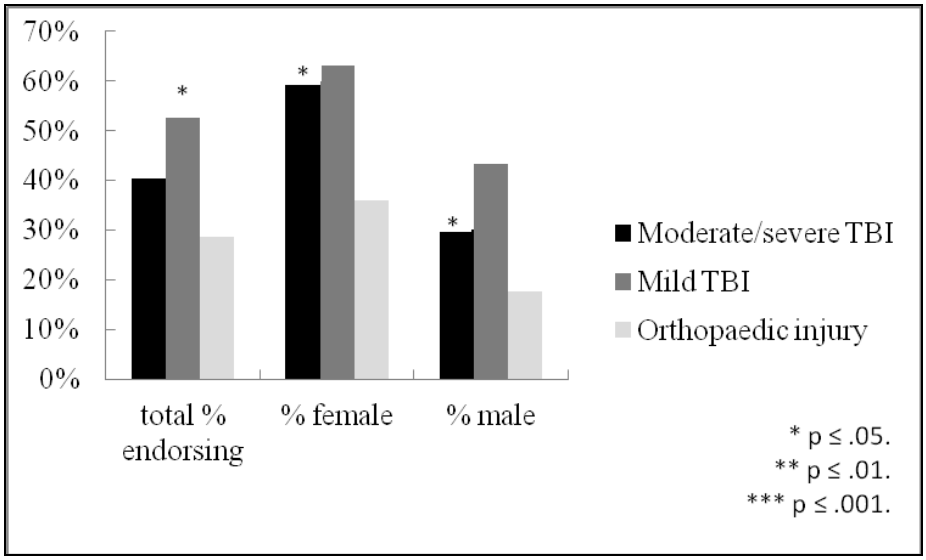

Figure 1. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed symptoms consistent with a diagnosis of Major Depressive Disorder.

Binary logistic regression was performed to assess the impact of the different injury groups, sex, age at injury and the number of years post-injury on the likelihood that respondents would endorse having had symptoms consistent with MDD. The full model containing all predictors indicated a significant association between the variables in the model and rates of MDD {X^2 (3, *N=161)=9.93*, $p \leq .05$}. The Hosmer and Lemeshow test was non-significant, demonstrating that the model's estimates fit the data at an acceptable level {X^2 (8, N=161)=9.06, p=.34}. The model as a whole correctly classified 65.8% of the cases.

Two of the independent variables made a uniquely statistically significant contribution to the model (mTBI and sex) (Table 5). The strongest significant predictor of reporting MDD was being in the mTBI group. Individuals in this group were 3.17 times more likely to report MDD than the orthopaedic injury group ($p \leq .05$). Following this, female participants in general (across the three injury groups) were 2.71 times more likely than males to report MDD ($p \leq .01$). Although not significant, individuals in the moderate/severe TBI group were 2.09 times more likely to report MDD than those in the orthopaedic injury group (p=.11). Age at injury and number of years post-injury

were also not significantly associated with an increased likelihood of endorsing MDD (p=.40 and p=.26 respectively). When looking more specifically at sex as a predictor in each injury group, females were significantly more likely to report MDD than males in the moderate/severe TBI group only, and by 3.37 times ($p \leq .05$) (Table 6). Although not significant, females were also 2.22 times more likely than males to report MDD in the mTBI group (p=.14) and 2.63 times more likely in the orthopaedic injury group (p=.20).

Table 5

Logistic Regression Predicting Likelihood of Major Depressive Disorder.

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury			5.787	2		.055	
Moderate/severe TBI(1)	.74	.46	2.58	1	2.09	.108	[0.85, 5.13]
Mild TBI(2)	1.15	.48	5.75	1	3.17*	.016	[1.24, 8.14]
Age at injury	.05	.06	.71	1	1.05	.400	[0.94, 1.18]
Years post-injury	.06	.05	1.26	1	1.06	.262	[0.96, 1.17]
Sex [a]	1.00	.35	8.03	1	2.71**	.005	[1.36, 5.40]
Constant	-2.71	1.20	5.12	1	.07	.024	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Female compared with male sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 6

Sex Difference in Likelihood of Major Depressive Disorder per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Major Depressive Disorder							
Moderate/severe TBI [a]	1.22	.554	4.81	1	3.37*	.028	[1.14, 9.99]
Mild TBI [a]	.80	.543	2.17	1	2.22	.141	[0.77, 6.44]
Orthopaedic injury [a]	.97	.761	1.61	1	2.63	.204	[0.60, 11.65]

[a] Female compared with male sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$

Anxiety disorders. A total of 19.3% of participants reported at least one anxiety disorder. When broken down by group, 19.4% of participants in the moderate/severe TBI group, 28.1% of the mTBI group and 7.1% of the orthopaedic injury group endorsed symptoms consistent with an anxiety disorder, the difference between the groups was significant ($p \leq .05$) (Table 7). When sex was considered, 40.9% of females compared with 7.5% of males in the moderate/severe TBI group; 44.4% of females compared with 13.3% of males in the mTBI group; and 8% of females compared with 5.9% of males in the orthopaedic group reported symptoms consistent with an anxiety disorder. The sex differences were significant in the moderate/severe and mTBI group but not in the orthopaedic injury group (Figure 2).

Table 7

Amount of Female and Male Participants per Injury Group who Endorsed Symptoms Consistent with an Anxiety Disorder.

	Total N	N endorsed (%)	X^2	*p*
Anxiety Disorder				
Moderate/Severe TBI	62	12 (19.4%)*	10.15	.001
Female	22	9 (40.9%)***		
Male	40	3 (7.5%)***		
Mild TBI	57	16 (28.1%)*	6.81	.009
Female	27	12 (44.4%)**		
Male	30	4 (13.3%)**		
Orthopaedic injury	42	3 (7.1%)*	.07	.794
Female	25	2 (8%)		
Male	17	1 (5.9%)		
Total	161	31 (19.3%)*	6.81	.033

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

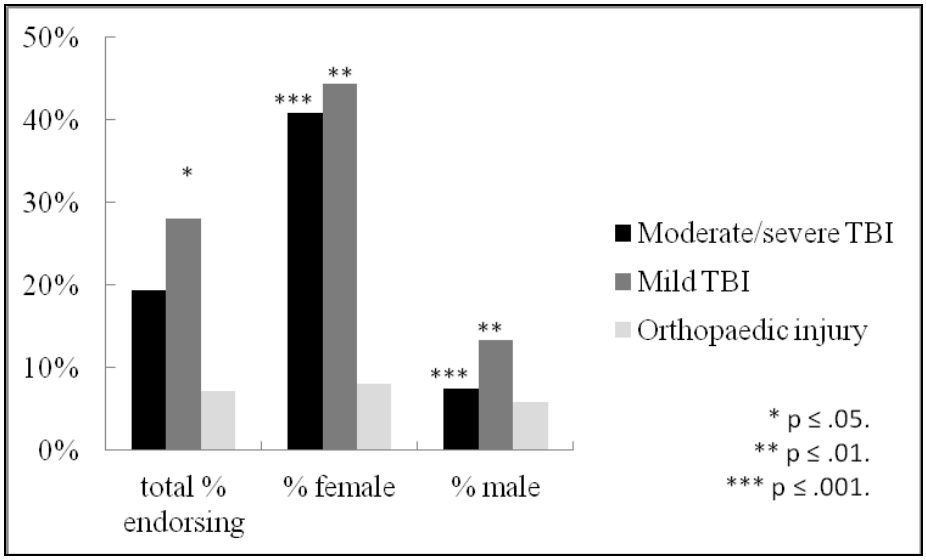

Figure 2. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed symptoms consistent with an anxiety disorder.

Binary logistic regression containing the variables: group, sex, age at injury and the number of years post-injury was performed to determine the likelihood that respondents would endorse having had symptoms consistent with a diagnosis of an anxiety disorder (Table 8). The full model containing all predictors showed a significant association between the variables in the model and the rates of an anxiety disorder {X^2 (5, *N=161)*=26.66, $p \leq .001$}. The Hosmer and Lemeshow test was non-significant, indicating that the model's estimates fit the data at an acceptable level {X^2 (8, N=161)=9.40, p=.31}. The model as a whole correctly classified 79.5% of the cases.

Three of the independent variables made a statistically significant contribution to the model (moderate/severe TBI, mTBI and sex). The strongest significant predictor of reporting anxiety disorders was being in the mTBI group where individuals were 5.81 times more likely to report an anxiety disorder than the orthopaedic injury group ($p \leq .05$). This was followed by sex, whereby females were significantly, and by 5.74 times, more likely than males to report an anxiety disorder ($p \leq .001$). Finally, those in the moderate/severe TBI group were significantly by 4.57 times more likely to endorse symptoms consistent with an anxiety disorder than individuals in the orthopaedic injury group ($p \leq .05$). Age at injury and the number of years post-injury were not significantly

associated with an increase in rates of anxiety disorders (p=.38 and p=.08 respectively) (Table 8). More specifically in terms of sex, females were significantly more likely to report an anxiety disorder than males in the moderate/severe TBI group by 8.54 times (p≤.01) and by 5.20 times in the mTBI group (p≤.01). The sex difference was not significant in the orthopaedic injury group (p=.79) (Table 9).

Table 8

Logistic Regression Predicting Likelihood of an Anxiety Disorder.

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury		.72	6.00	2		.050	
Moderate/severe TBI(1)	1.52	.74	4.47	1	4.57*	.035	[1.12, 18.69]
Mild TBI (2)	1.76	.08	5.71	1	5.81*	.017	[1.37, 24.64]
Age at injury	.07	.07	.79	1	1.07	.375	[0.92, 1.26]
Years post-injury	.12	.48	3.03	1	1.13	.082	[0.99, 1.30]
Sex [a]	1.75	1.85	13.05	1	5.74***	.000	[2.22, 14.80]
Constant	-6.10		10.86	1	.002	.001	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Female compared with male sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 9

Sex Difference in Likelihood of an Anxiety Disorder per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Anxiety Disorder							
Moderate/severe TBI [a]	2.15	.74	8.39	1	8.54**	.004	[2.00, 36.5]
Mild TBI [a]	1.65	.66	6.20	1	5.20**	.013	[1.42, 19.04]
Orthopaedic injury [a]	.33	1.27	.07	1	1.39	.794	[0.12, 16.18]

[a] Female compared with male sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Internalising disorders. Overall 46.6% of participants reported internalising disorders; 43.5% of participants in the moderate/severe TBI group, 63.2% of the mTBI group and 28.6% of the orthopaedic injury group (Table 10). The differences between groups were significant (p≤01). When evaluated by sex, 63.6% of females compared with 32.5% of males in the moderate/severe TBI group; 81.5% of females compared with 46.7% of males in the mTBI group; and 36% of females reported compared with 17.6% of males in the orthopaedic group reported internalising disorder (Figure 3). The sex differences were significant for those with moderate/severe TBI ($p \leq .05$) and mTBI ($p \leq .01$) but not for those in the orthopaedic injury group ($p = .20$).

Table 10

Amount of Female and Male Participants per Injury Group who Endorsed Symptoms Consistent with an Internalising Disorder.

	Total N	N endorsed (%) [a]	X^2	*p*
Internalising Disorder				
Moderate/Severe TBI	62	27 (43.5%)**	5.60	.018
Female	22	14 (63.6%)*		
Male	40	13 (32.5%)*		
Mild TBI	57	36 (63.2%)**	7.40	.007
Female	27	22 (81.5%)**		
Male	30	14 (46.7%)**		
Orthopaedic injury	42	12 (28.6%)**	1.67	.196
Female	25	9 (36%)		
Male	17	3 (17.6%)		
Total	161	75 (46.6%)**	12.00	.002

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

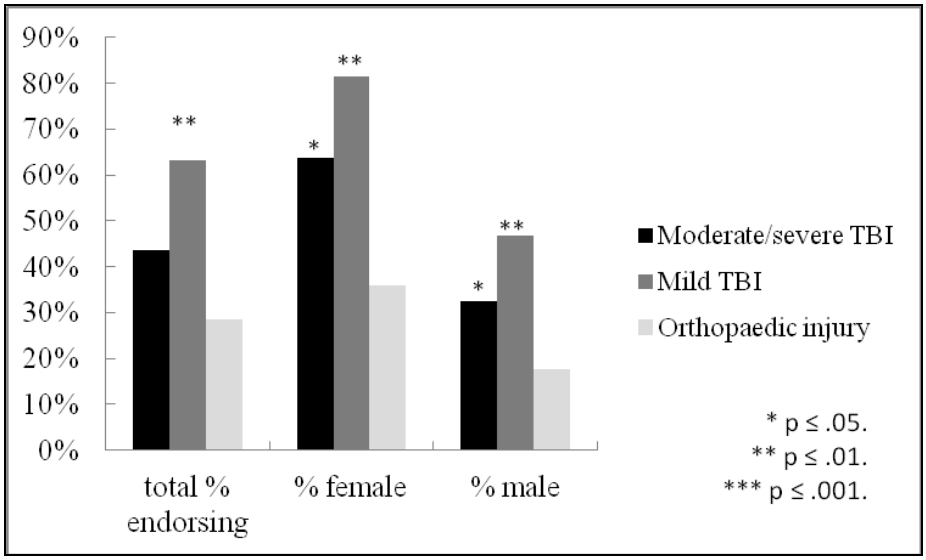

Figure 3. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed symptoms consistent with an internalising disorder.

The binary logistic regression model containing four independent variables (group, age at injury, number of years post-injury, and sex) was statistically significant {X^2 (5, *N=161)*=28.49, $p \leq .001$}. The Hosmer and Lemeshow test indicated that the model fit the data at an acceptable level {X^2 (8, N=161)=3.51, p=.90}. The model as a whole correctly classified 69.6% of the cases.

Three of the independent variables made a statistically significant contribution to the model (mTBI, moderate/severe TBI and sex) (Table 11). The strongest significant predictor of internalising disorders was being in the mTBI group, individuals in this group were 5.80 times more likely to report internalising disorders than those in the orthopaedic injury group ($p \leq .001$). This was followed by sex, where females were 3.87 times more likely than males to report internalising disorders ($p \leq .001$). Individuals in the moderate/severe TBI group were 2.70 times more likely than those in the orthopaedic injury group to report an internalising disorder ($p \leq .05$). Increasing age at injury and number of years post-injury were not significantly associated with increased risk of internalising disorders (p=.29 and p=.22 respectively). Females were significantly more likely to report internalising disorders than males in the moderate/severe TBI group by 3.63 times ($p \leq .05$) and by 5.03 times in the mTBI group ($p \leq .01$). Females were also more likely than males to report

internalising disorders in the orthopaedic injury group by 2.63 times but this was not statistically significant ($p \leq .20$) (Table 12).

Table 11

Logistic Regression Predicting Likelihood of an Internalising Disorder.

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury			12.16	2		.002	
Moderate/severe TBI(1)	1.00	.47	4.44	1	2.70*	.035	[1.07, 6.82]
Mild TBI (2)	1.76	.50	12.15	1	5.80***	.000	[2.16, 15.58]
Age at injury	.06	.06	1.14	1	1.07	.286	[0.95, 1.19]
Years post-injury	.06	.05	1.51	1	1.07	.219	[0.96, 1.18]
Sex [a]	1.35	.37	13.29	1	3.87***	.000	[1.87, 8.00]
Constant	-3.22	1.25	6.58	1	.04	.010	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Female compared with male sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 12

Sex Difference in Likelihood of an Internalising Disorder per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Internalising Disorder							
Moderate/severe TBI [a]	1.29	.56	5.37	1	3.63*	.021	[1.22, 10.83]
Mild TBI [a]	1.62	.62	6.88	1	5.03**	.009	[1.50, 16.82]
Orthopaedic injury [a]	.97	.76	1.61	1	2.63	.204	[0.59, 11.65]

[a] Female compared with male sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Offending behaviour. Overall 22.4% of participants reported a history of offending. However, offending rates varied depending on the injury group, with 35.5% of participants in the moderate/severe TBI group, 17.5% of the mTBI group and 9.5% of the orthopaedic injury group reporting offending behaviour. The difference between the injury groups was significant ($p \leq .01$). Although the sex differences were not significant in any of the three injury groups, 22.7% of females compared with 42.5% of males in the moderate/severe TBI group; 7.4% of females compared with 26.7% of males in the mTBI group and 8% of females compared with 11.8% of males in the orthopaedic injury group, endorsed offending behaviour (Table 13 and Figure 4).

Table 13

Amount of Female and Male Participants per Injury Group who Endorsed Offending Behaviour.

	Total N	N endorsed (%) [a]	X^2	*p*
Offending Behaviour				
Moderate/Severe TBI	62	22 (35.5%)**	2.42	.119
Female	22	5 (22.7%)		
Male	40	17 (42.5%)		
Mild TBI	57	10 (17.5%)**	3.64	.056
Female	27	2 (7.4%)		
Male	30	8 (26.7%)		
Orthopaedic injury	42	4 (9.5%)**	.17	.683
Female	25	2 (8%)		
Male	17	2 (11.8%)		
Total	161	36 (22.4%)**	10.90	.004

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

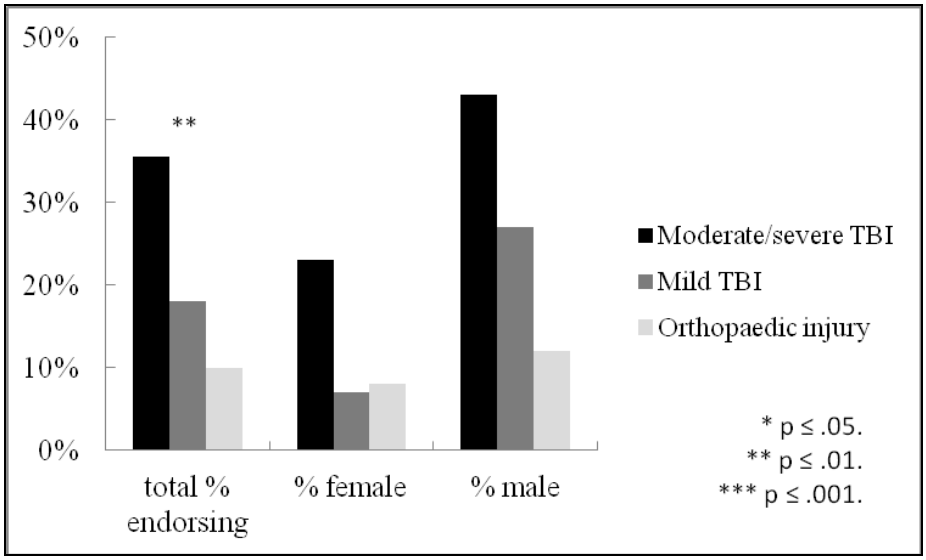

Figure 4. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed offending behaviour.

The binary logistic regression model, containing all variables showed a significant association between the variables in the model and rates of offending {X^2 (5, *N=161)*=24.27, $p \leq .001$}. The Hosmer and Lemeshow test indicated that the model's estimates fit the data at an acceptable level {X^2 (8, N=161)=13.23, p=.10}. The model correctly classified 78.3% of the cases.

Four of the independent variables made a statistically significant contribution to the model (moderate/severe TBI, sex, age at injury, and the number of years post-injury) (Table 14). The strongest significant predictor of offending was moderate/severe TBI; individuals in this group were 3.78 times more likely to report offending than the orthopaedic injury group ($p \leq .05$). This was followed by sex, where male participants were 2.84 times more likely than females to report offending ($p \leq .05$), however, sex was not a significant predictor when the injury groups were split (Table 15). As the age at injury increased, the likelihood of offending increased by 16% per year, relative to an equivalent person with one less year at age at injury ($p \leq .05$). Finally, as the number of years post-injury increased, the likelihood of reporting offending increased by 17 %, relative to an equivalent person with one year less since their injury ($p \leq .01$). Lastly, individuals in the mTBI group were 1.67

times more likely to report offending than those in the orthopaedic injury group, although this was not significant (p=.45).

Table 14

Logistic Regression Predicting Likelihood of Offending Behaviour.

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury			6.00	2		.050	
Moderate/severe TBI(1)	1.33	.61	4.71	1	3.78*	.030	[1.14, 12.55]
Mild TBI (2)	.52	.68	.58	1	1.67	.448	[0.44, 6.33]
Age at injury	.15	.07	4.71	1	1.16*	.030	[1.02, 1.34]
Years post-injury	.16	.06	6.47	1	1.17**	.011	[1.04, 1.32]
Sex [a]	1.04	.45	5.37	1	2.84*	.020	[1.18, 6.87]
Constant	-5.16	1.52	11.45	1	.01	.001	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 15

Sex Difference in Likelihood of Reporting Offending Behaviour per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Offending Behaviour							
Moderate/severe TBI [a]	.92	.60	2.35	1	2.51	.125	[0.77, 8.16]
Mild TBI [a]	1.51	.84	3.23	1	4.55	.072	[0.87, 23.72]
Orthopaedic injury [a]	.43	1.05	.17	1	1.53	.685	[0.19, 12.09]

[a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Arrests. A total of 16.1% of participants reported that they had been arrested; specifically, in the moderate/severe TBI group 24.2% had been arrested compared with 12.3% of the mTBI group, and 9.5% of the orthopaedic injury group (Table 16). The difference between the groups was not significant (p=.08). Considering sex, 13% of females compared with 32.5% of males in the moderate/severe TBI group had been arrested; in the mTBI group 3.7% of females had been arrested, compared with 20% of males; and in the orthopaedic injury group 8% of females had been arrested, compared with 11.8% of males. The sex differences were significant in the moderate/severe TBI group ($p \leq .04$) but were not in the mTBI or orthopaedic injury group (p=.06 and p=.68 respectively) (Figure 5).

Table 16

Amount of Female and Male Participants per Injury Group who Endorsed Past Arrests.

	Total N	N endorsed (%) [a]	X^2	p
Arrests				
Moderate/Severe TBI	62	15 (24.2%)	4.24	.039
Female	22	2 (9.1%)*		
Male	40	13 (32.5%)*		
Mild TBI	57	7 (12.3%)	3.50	.061
Female	27	1 (3.7%)		
Male	30	6 (20%)		
Orthopaedic injury	42	4 (9.5%)	.17	.683
Female	25	2 (8%)		
Male	17	2 (11.8%)		
Total	161	26 (16.1%)	4.95	.084

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

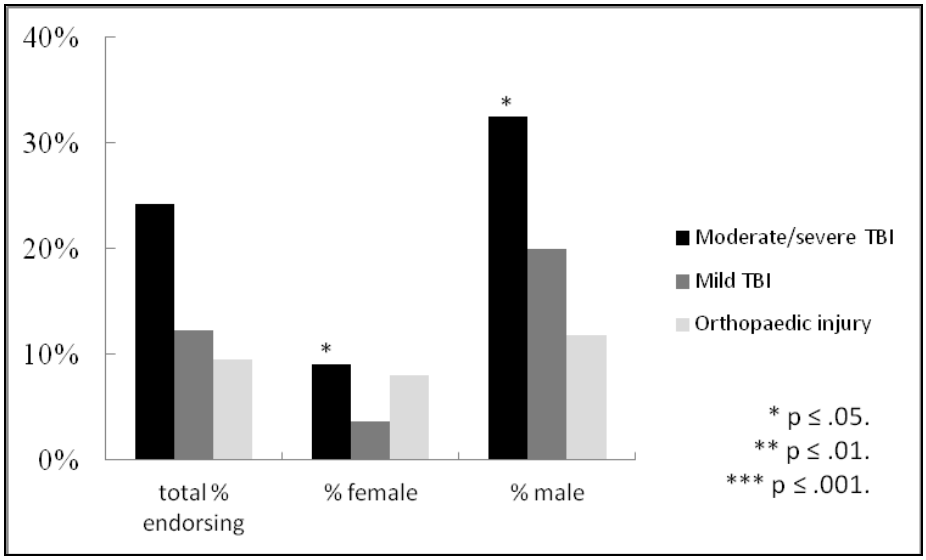

Figure 5. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed past arrests.

A binary logistic regression containing all four independent variables indicated that there is a significant association between the variables in the model and rates of reported arrests {X^2 (5, *N=161)*=16.94, $p \leq .01$}. The Hosmer and Lemeshow test showed the model's estimates fit the data at an acceptable level {X^2 (8, N=161)=7.49, p=.49}. The model correctly classified 83.9% of the cases.

The strongest significant predictor of arrests was sex. Generally, males were significantly, and by 4.05 times, more likely than females to have been arrested ($p \leq .01$) (Table 17); however, when split by injury group, the sex differences were only significant in the moderate/severe TBI group, whereby males were 4.82 times more likely than females to have been arrested ($p \leq .05$) (Table 18). Although not significant, individuals in the moderate/severe TBI group were 2 times more likely to have been arrested than the orthopaedic injury group ($p \leq .28$). As the number of years post-injury increased, the likelihood of reporting offending significantly increased by 14% relative to an equivalent person with one year less since their injury ($p \leq .05$). Age at injury was not significantly associated with having been arrested (p=.10).

Table 17

Logistic Regression Predicting Likelihood of Arrests.

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury			2.16	2		.340	
Moderate/severe TBI(1)	.69	.63	1.19	1	2.00	.275	[0.58, 6.91]
Mild TBI (2)	.003	.72	.00	1	1.00	.997	[0.25, 4.08]
Age at injury	.12	.08	2.64	1	1.13	.104	[0.98, 1.31]
Years post-injury	.13	.07	3.95	1	1.14*	.047	[1.00, 30]
Sex [a]	1.40	.54	6.62	1	4.05**	.010	[1.40, 11.76]
Constant	-4.40	1.60	7.58	1	.01	.000	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 18

Sex Difference in Likelihood of Reporting Arrests per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Arrests							
Moderate/severe TBI [a]	1.57	.82	3.72	1	4.82*	.054	[0.98, 23.78]
Mild TBI [a]	1.87	1.12	2.81	1	6.50	.094	[0.73, 57.99]
Orthopaedic injury [a]	.43	1.05	.17	1	1.53	.685	[0.19, 12.09]

[a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Diversions and/or convictions. A total of 18% of participants reported a diversion and/or conviction. Spilt by group, 27.4% of participants in the moderate/severe TBI group, 15.8% of the

mTBI group and 7.1% of the orthopaedic injury group had a diversion and/or conviction. The differences between groups were significant ($p \leq .03$) (Table 19). It was found that 13.6% of females compared with 35% of males in the moderate/severe TBI group; 3.7% of females compared with 26.7% of males in the mTBI group, and 8% of females compared with 5.9% of males reported a diversion and/or conviction (Figure 6). The sex differences were significant in the mTBI group ($p \leq .05$) but not in the other injury severity groups (Table 19).

Table 19

Amount of Female and Male Participants per Injury Group who Endorsed Having Had a Diversion and/or Conviction.

	Total N	N endorsed (%) [a]	X^2	*p*
Diversion or Conviction				
Moderate/Severe TBI	62	17 (27.4%)*	3.26	.071
Female	22	3 (13.6%)		
Male	40	14 (35%)		
Mild TBI	57	9 (15.8%)*	5.64	.018
Female	27	1 (3.7%)*		
Male	30	8 (26.7%)*		
Orthopaedic injury	42	3 (7.1%)*	.07	.794
Female	25	2 (8%)		
Male	17	1 (5.9%)		
Total	161	29 (18%)*	7.27	.026

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

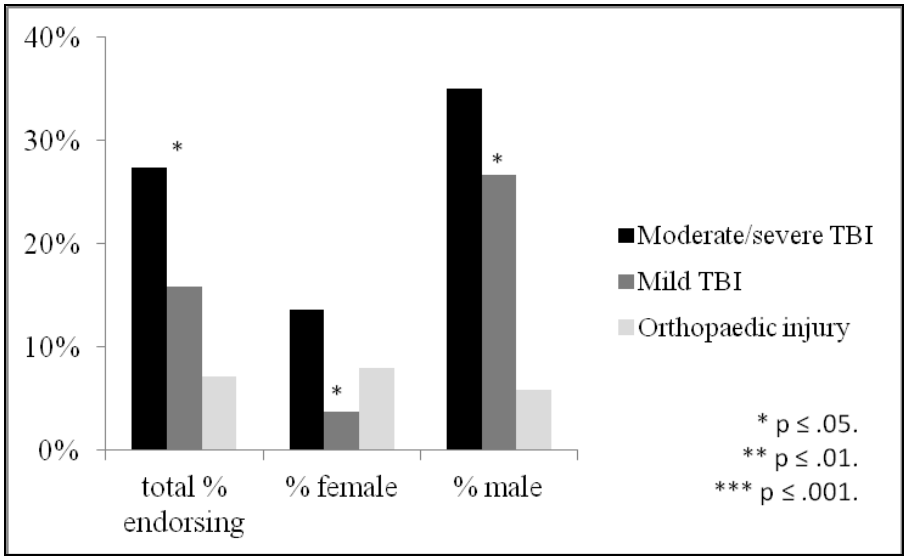

Figure 6. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed having had a diversion and/or conviction.

The binary logistic regression model was statistically significant, indicating a significant association between the variables in the model and rates of having had a diversion and/or conviction $\{X^2 (5, N=161)=21.24, p\leq.001\}$. The Hosmer and Lemeshow test indicated that the model fit the data at a satisfactory level $\{X^2 (8, N=161)=8.97, p=.35\}$. The model correctly classified 82.6% of the cases.

Sex, age at injury and number of years post-injury made a statistically significant contribution to the model (Table 20). Significantly, males in general were 3.51 times more likely than females to report a diversion and/or conviction ($p\leq.01$). As age at injury increased, the likelihood of a diversion and/or conviction increased by 18% times per year relative to an equivalent person with one year less at age of injury ($p\leq.05$). Finally, as the number of years post-injury increased, the likelihood of reporting a diversion and/or conviction increased by 16 % relative to an equivalent person with one year less since their injury ($p\leq.05$). Neither being in the moderate/severe TBI group nor the orthopaedic injury group was a significant predictor of a diversion and/or conviction. In terms of sex, males were significantly more likely to report a diversion and/or conviction than females in the mTBI

group, this was by 9.46 times ($p \leq .04$). Sex, however, was not a significant predictor of diversion and/or conviction in the moderate/severe TBI or orthopaedic injury group (Table 21).

Table 20

Logistic Regression Predicting Likelihood of a Diversion and/or Conviction.

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury			3.34	2		.189	
Moderate/severe TBI(1)	1.22	.69	3.11	1	3.37	.078	[0.87, 13.03]
Mild TBI (2)	.75	.75	.99	1	2.11	.321	[0.48, 9.19]
Age at injury	.17	.08	4.68	1	1.18*	.031	[1.02, 1.37]
Years post-injury	.15	.07	5.28	1	1.16*	.022	[1.02, 1.32]
Sex [a]	1.26	.51	6.04	1	3.51**	.014	[1.29, 9.56]
Constant	-6.75	1.69	15.87	1	.004	.000	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 21

Sex Difference in Likelihood Reporting a Diversion and/or Conviction per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Diversion and/or conviction							
Moderate/severe TBI [a]	1.23	.70	3.04	1	3.41	.081	[0.86, 13.56]
Mild TBI [a]	2.25	1.10	4.18	1	9.46*	.041	[1.10, 81.57]
Orthopaedic injury [a]	-.33	1.27	.07	1	.72	.794	[0.06, 8.62]

[a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Substance abuse and/or dependence. Overall, 22.4% of all participants reported substance abuse and/or dependence: 33.9% of participants in the moderate/severe TBI group, 21.1% of the mTBI group, and 7.1% of the orthopaedic injury group, and the difference between groups was significant ($p \leq .01$) (Table 22 and Figure 7). In terms of sex, 22.7% of females compared with 40% of males in the moderate/severe TBI group; 7.4% of females compared with 33.3% of males in the mTBI group; and 4% of females compared with 11.8% of males in the orthopaedic injury group reported substance abuse and/or dependence. The sex differences, were significant in the mTBI ($p \leq .05$) group but not in the moderate/severe TBI or orthopaedic injury group ($p = .17$ and $p = .34$ respectively).

Table 22

Amount of Female and Male Participants per Injury Group who Endorsed Symptoms Consistent with Substance Abuse and/or Dependence.

	Total N	N endorsed (%)	X^2	*p*
Substance abuse and/or dependences				
Moderate/Severe TBI	62	21 (33.9%)**	1.89	.169
Female	22	5 (22.7%)		
Male	40	16 (40%)		
Mild TBI	57	12 (21.1%)**	5.75	.017
Female	27	2 (7.4%)*		
Male	30	10 (33.3%)*		
Orthopaedic injury	42	3 (7.1%)**	.92	.338
Female	25	1 (4%)		
Male	17	2 (11.8%)		
Total	161	36 (22.4%)**	10.39	.006

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

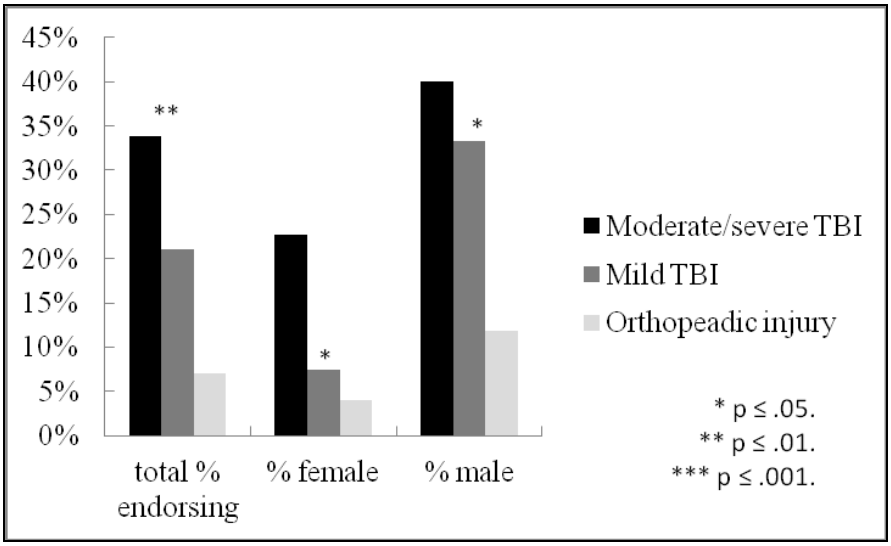

Figure 7. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed symptoms consistent with substance abuse and/or dependence.

The binary logistic regression model containing all predictors was statistically significant {X^2 (5, *N=161)*=20.36, $p \leq .001$} and the Hosmer and Lemeshow test showed that the model's estimates fit the data at an acceptable level {X^2 (8, N=161)=7.98, p=.44}. The model as a whole correctly classified 78.9% of the cases.

Moderate/severe TBI and sex made a statistically significant contribution to the model (Table 23). The strongest significant predictor of substance abuse and/or dependence was moderate/severe TBI; participants in this group were 5.17 times more likely to report substance abuse and/or dependence than those in the orthopaedic injury group ($p \leq .05$). Males in general were also significantly, by 3.48 times, more likely than females to report substance abuse and/or dependence ($p \leq .01$). This was, however, significant only in the mTBI group, where males were more likely to report substance abuse and/or dependence than females by 6.25 times ($p \leq .05$) (Table 24). Males were also 2.27 and 3.20 times more likely to report substance abuse and/or dependence than females in the moderate/severe TBI and orthopaedic injury group respectively, although this was not significant in either of the control groups (p=.17 and p=.36). Age at injury and number of years post-injury were not

significantly associated with the incidence of substance abuse and/or dependence in any of the injury groups (p=.79 and p=.42 respectively).

Table 23

Logistic Regression Predicting Likelihood of Substance Abuse and/or Dependence.

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury			6.55	2		.038	
Moderate/severe TBI(1)	1.64	.67	5.96	1	5.17*	.015	[1.38, 19.30]
Mild TBI (2)	1.01	.71	2.01	1	2.75	.156	[0.68, 11.12]
Age at injury	.02	.06	.08	1	1.02	.785	[0.90, 1.15]
Years post-injury	.05	.06	.66	1	1.05	.416	[0.94, 1.17]
Sex [a]	1.25	.46	7.49	1	3.48**	.006	[1.42, 8.49]
Constant	-3.92	1.38	8.13	1	.02	.004	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 24

Sex Difference in Likelihood of Endorsing Substance Abuse and/or Dependence per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Substance abuse and/or dependence							
Moderate/severe TBI [a]	.82	.60	1.85	1	2.27	.174	[0.70, 7.38]
Mild TBI [a]	1.83	.83	4.87	1	6.25*	.027	[1.23, 31.84]
Orthopaedic injury [a]	1.16	1.27	.84	1	3.20	.359	[0.27, 38.42]

[a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$

Externalising behaviours. A total of 46.8% of participants reported externalising behaviours; more specifically, 46.8% of participants in the moderate/severe TBI group, 35.1% of the mTBI group and 14.3% of the orthopaedic injury group reported externalising behaviours, and the differences between group were significant, ($p \leq .01$) (Table 25 and Figure 8). In terms of sex, 31.8% of females compared with 55% of males in the moderate/severe TBI group; 14.8% of females as opposed to 53.5% of males in the mTBI group, and 12% of females compared with 17.6% of males in the orthopaedic injury group reported externalising behaviours. The sex difference was significant in the mTBI group only ($p \leq .01$).

Table 25

Amount of Female and Male Participants per Injury Group who Reported Externalising Behaviours.

	Total N	N endorsed (%)	X^2	*p*
Externalising Behaviours				
Moderate/Severe TBI	62	29 (46.8%)**	3.06	.080
Female	22	7 (31.8%)		
Male	40	22 (55%)		
Mild TBI	57	20 (35.1%)**	9.26	.002
Female	27	4 (14.8%)**		
Male	30	16 (53.3%)**		
Orthopaedic injury	42	6 (14.3%)**	.26	.608
Female	25	3 (12%)		
Male	17	3 (17.6%)		
Total	161	75 (46.9%)**	11.78	.003

Note. X^2 = Pearson's Chi Square; CI = confidence interval; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

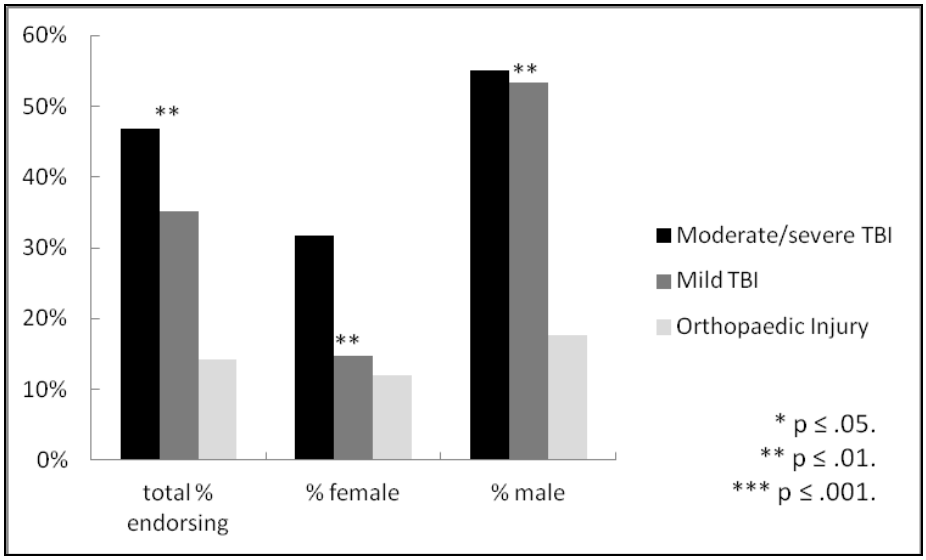

Figure 8. Amount of participants in each injury group, and the amount of female and male participants in each injury group who endorsed externalising behaviours.

The binary logistic regression model containing all predictors was statistically significant {X^2 (5, *N=161)*=24.97, $p \leq .001$}. The Hosmer and Lemeshow test was non-significant, indicating that the model's estimates fit the data at an acceptable level {X^2 (8, N=161)=7.22, p=.51}. The model as a whole correctly classified 70.8% of the cases.

Two of the independent variables, namely moderate/severe TBI and sex, made a statistically significant contribution to the model (Table 26). The strongest significant predictor of externalising behaviours was being in the moderate/severe TBI group, individuals in this group were 4.12 times more likely to report externalising behaviours than those in the orthopaedic injury group ($p \leq .01$). Participants in the mTBI group were 2.69 times more likely to report externalising behaviours than those in the orthopaedic injury group but this was not significant (p=.08). Males were significantly more likely than females to report externalising behaviours by 3.48 times ($p \leq .001$) in general. This difference was only significant in the mTBI group, whereby males were 6.57 times more likely than females to endorse externalising behaviours ($p \leq 05$) (Table 27).

Table 26

Logistic Regression Predicting Likelihood of Externalising Behaviours

	B	S.E	Wald	df	ExpB	*p*	95% C.I
Orthopaedic injury			7.20	2		.027	
Moderate/severe TBI(1)	1.42	.53	7.18	1	4.12**	.007	[1.46, 11.58]
Mild TBI (2)	.988	.56	3.13	1	2.69	.077	[0.90, 8.02]
Age at injury	.031	.06	.29	1	1.03	.588	[0.92, 1.16]
Years post-injury	.053	.05	1.06	1	1.05	.303	[0.95, 1.17]
Sex [a]	1.25	.38	10.56	1	3.48***	.001	[1.64, 7.38]
Constant	-3.34	1.20	7.75	1	.04	.005	

Note. SE = standard error; CI = confidence interval; df = degrees of freedom; [a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table 27

Sex Difference in Likelihood of Reporting Externalising Behaviours per Injury Group.

	B	SE	Wald	df	ExpB	*p*	95% CI
Externalising Behaviours							
Moderate/severe TBI [a]	.96	.56	2.99	1	2.62	.084	[0.88, 7.81]
Mild TBI [a]	1.88	.65	8.29	1	6.57**	.004	[1.83, 23.67]
Orthopaedic injury [a]	.45	.89	.26	1	1.57	.610	[0.28, 8.91]

[a] Male compared with female sex; * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Summary

In terms of psychiatric disorders, the strongest significant predictor of reporting symptoms consistent with MDD, anxiety disorders, and internalising disorders was being in the mTBI group, where individuals were 3.17 times more likely to report MDD; 5.81 times more likely to report an anxiety disorder; and 5.80 times more likely to endorse symptoms consistent with an internalising disorder than those in the orthopaedic injury group. Individuals in the moderate/severe TBI group were significantly, and by 4.57 times, more likely to endorse symptoms consistent with an anxiety disorder and significantly, by 2.70 times, more likely to report an internalising disorder than those in the orthopaedic injury group.

In contrast, moderate/severe TBI was the strongest significant predictor of reporting offending, substance abuse and/or dependence and externalising behaviours. More specifically, compared to those in the orthopaedic injury group, individuals in the moderate/severe TBI were 3.78 times more likely to report offending, were 5.17 times more likely to report substance abuse and/or dependence and were 4.12 times more likely to report externalising behaviours overall. The likelihood of reporting externalising behaviours in general was increased in the mTBI group when compared to the orthopaedic injury group, although this was not statistically significant.

When considering sex, females were significantly, by 2.71 times, more likely than males to report MDD; 5.74 times more likely than males to report an anxiety disorder and were 3.87 times more likely than males to report an internalising disorder in general. This trend was also found in the mTBI group where females were significantly more likely than males to report anxiety disorders by 5.20 times and internalising disorders by 5.03 times. Females with moderate/severe TBI were significantly more likely to report MDD, anxiety disorders and internalising disorders than males with moderate/severe TBI by 3.37 times, 8.54 times and 3.63 times respectively. Sex was not significantly associated with an increased risk of reporting any of the internalising disorders in the orthopaedic injury group.

Conversely, males were significantly more likely, by 2.84 times, to report offending, 4.05 times more likely to have been arrested, were 3.51 times more likely to report a diversion and/or conviction, were 3.48 times more likely to report substance abuse and/or dependence, and were 3.48 times more likely to report externalising behaviours in general than females. Males in the moderate/severe TBI were significantly more likely by 4.82 times to report a past arrest. Males in the mTBI group were significantly more likely to report a diversion and/or conviction by 9.46 times; were more likely to report substance abuse and/or dependence by 6.25 times and were 6.57 times more likely to report externalising behaviours in general than females. Sex was not significantly associated with an increased likelihood of reporting any externalising behaviours in the orthopaedic injury group.

Age at injury as a continuous variable was not a significant predictor of any internalising disorders (i.e. depression or anxiety). It was, however, significantly associated with offending behaviour, and diversions and/or convictions; whereby, as age at injury increased, the likelihood of offending and of reporting a diversion and/or conviction increased by 16-18% relative to an equivalent person with one year less in terms of their age at injury. Increasing number of years post injury was a statistically significant predictor of offending, arrests and diversions and/or convictions only, where the risk of reporting one of these behavioural difficulties increased by 14-17% relative to an equivalent person with one year less since their injury.

CHAPTER 4

DISCUSSION

Findings

The aim of this study was to examine the long-term, adult psychiatric and behavioural outcomes following paediatric mTBI acquired between 1-17 years of age. The following was found:

Internalising disorders. As expected, individuals with mTBI were significantly more likely to report symptoms consistent with MDD by 3.17 times; anxiety disorders by 5.81 times; and internalising disorders in general by 5.80 times than those in the orthopaedic injury group. Those in the moderate/severe TBI groups were also at significantly greater risk of anxiety disorders, and internalising disorders in general but were not at significantly greater risk of MDD than orthopaedic controls. What was not expected was that the risk of all internalising disorders for those with mTBI would be higher than that faced by those with moderate/severe TBI. The fact that individuals with mTBI may be at greater risk of internalising disorders than even those with moderate/severe TBI is noteworthy and important for health care providers to be aware of in order for them to offer effective assessment and appropriate intervention for affected individuals.

Although unanticipated, this finding may be explained by differences in executive functioning between the mTBI group and the moderate/severe TBI group. Cooper-Evans et al. (2008), reported that individuals with severe *acquired brain injury* who were functioning at a higher cognitive level and had more insight into their deficit, reported lower levels of self-esteem. This may explain our finding, whereby individuals with mTBI, who have greater insight, may be at increased risk for developing depression and anxiety when compared with moderate/severe TBI.

Finding that those with mTBI were at greater risk of internalising disorders than even those with moderate/severe TBI was unexpected. Nonetheless, other research tends to suggest that rates of

internalizing disorders are likely to be at least as high in those with mTBI compared with moderate or severe TBI. Luis and Mittenberg (2002), found that rates of new onset of mood and anxiety disorders were similar in mild and moderate/severe paediatric TBI groups (injured between the ages of 6-15 years) and these were significantly higher than in the orthopaedic group six months post-injury. This included internalising disorders such as MDD, specific phobia, panic attack, agoraphobia, GAD, and PTSD. Further, Hawley (2003) concluded that in children aged 5-15 years at time of injury, both mild and moderate/severe TBI groups, at approximately two years post-injury, were significantly more anxious than healthy controls.

The current findings are however, in contrast with the following studies reporting on outcomes of paediatric mTBI, assessed before participants reached adulthood. Max, Koele, et al. (1998) found that mTBI and orthopaedic groups were not significantly different from each other in psychiatric status two years post-injury, however, this study had a relatively small sample size (n=24) of children between the ages of 5-14 with mTBI, which may have meant that the participant pool was not large enough to for group differences to be detected. Similarly, Max, Sharma et al. (1997) reported that in a child psychiatry inpatient unit, TBI (predominantly mild) (n=56) was not associated with increased rates of psychiatric disorders five years post-injury; the mean age of assessment was approximately 10 years of age. Although significant differences were not found, research has shown that psychiatric illness may only manifest several years post-injury and often when an individual is older than 20 years of age (Timonena et al., 2002). The expression of psychiatric illness may only become apparent in adulthood. In a longitudinal study that prospectively followed a birth cohort up to 16 years of age, McKinlay et al. (2009) reported increased rates of MDD but not anxiety disorders in individuals who sustained mTBI (n=76) before the age of five. This may have been because the age at which participants were assessed was between 14-16 years, a time of development, and it is possible that anxiety disorders would manifest at a later age. Unlike the studies by Max, Koele, et al. (1998) and Max, Sharma et al. (1997), Timonena et al. (2002) and McKinlay et al. (2009), made use of a birth cohort (N = 10 934 and initial N=1265), prospectively followed participants for over 5 years post paediatric TBI and both studies reported psychiatric outcomes post mTBI.

Externalising behaviours. For those in the mTBI group in the current study, the risk of offending, diversions and/or convictions, substance abuse and/or dependence and externalising behaviours was increased when compared with the orthopaedic injury group, however, these differences were not significant. Moderate/severe TBI was the strongest risk factor for all the externalising problems and was significantly so for offending (by 3.78 times); for substance abuse and/or dependence (by 5.17 times); and for externalising behaviours (by 4.12 times). Thus, it seems that paediatric moderate/severe TBI places individuals at greater risk for externalising problems than does paediatric mTBI, when compared to orthopaedic injury controls.

The dose-response pattern, i.e. increasing injury severity being associated with increasing behavioural difficulties, may be explained by damage to the frontal lobes, not uncommon in TBI (McKinlay et al., 2009). An association between aggressive dyscontrol and brain injury (especially involving the frontal lobes) was reported in a review of the literature on frontal lobe dysfunction and violent and criminal behaviour. The frontal systems have also been associated with impulse control, and consideration of consequences. In turn, dysfunction of this area may be linked to anti-social behaviours (Brower & Price, 2001; Williams et al., 2010). Thus more severe injury to this area of the brain may be associated with more impaired behavioural functioning. The link between frontal lobe damage and antisocial behaviour may help to explain why those with mTBI were at higher risk, although not significantly so, of the externalising behaviours when compared with the orthopaedic injury group, but were not at as great a risk as those with moderate/severe TBI.

The current findings are in line with prior research. For example, paediatric TBI (predominantly mild) has been significantly related to later criminality in male cohort members but was not significantly associated with later heavy alcohol use (Timonena et al., 2002). In this present study, both moderate/severe TBI and mTBI were associated with increased risk of offending behaviour, however, mTBI was not significantly so. In contrast to the present findings that there was no significant association between mTBI and externalising problems, another longitudinal study found that children who had been hospitalised for mTBI prior to the age of five were significantly

more likely to show symptoms of ADHD, CD/ODD and substance abuse (McKinlay et al., 2009). It would be interesting to see if such behavioural difficulties were still reported in adulthood.

Sex. The results clearly indicate a sex difference in outcome in those with TBI (mild and moderate/severe) above and beyond that found in the orthopaedic injury group. Females in the mTBI group were significantly more likely, by 5.20 times, to report an anxiety disorder and internalising disorder by 5.03 times, but female sex was not significantly associated with increased risk of MDD. Females with moderate/severe TBI were significantly more likely to report MDD, anxiety disorders and internalising disorders than those in the orthopaedic injury group by 3.37 times, 8.54 times and 3.63 times respectively. Importantly, while significant sex differences in the risk of internalising disorders were generally found in both TBI groups, there was no significant sex difference in risk of any internalising disorders in the orthopaedic injury group. This suggests that females with TBI are at significantly greater risk of experiencing an internalising disorder than males, with this risk being elevated when compared to that faced by females in the orthopaedic injury group. In sum, the current findings suggest that sex impacts on psychiatric outcomes of paediatric TBI (both mild and moderate/severe).

Distinct from the above, in the current study males with TBI, particularly males with mTBI, seem to be at greater risk of externalising behaviours than females. Significant differences between sex were generally found in the TBI groups (both mTBI and moderate/severe TBI); however males in the mTBI group seemed to be at significantly greater risk than females of developing externalising problems including: diversions and/or convictions by 9.46 times, substance abuse and/or dependence by 6.25 times, and externalising behaviours by 6.57 times, although male sex was not significantly associated with arrests or offending behaviour in the mTBI group. The difference between risk of externalising problems between sexes was less apparent in the moderate/severe TBI group whereby, males were only significantly more likely than females to report arrests by 4.82 times. Importantly there was no significant distinction between sex and risk of any of the externalising problems in the orthopaedic injury group, suggesting that sex has a significant impact in terms of behavioural

outcomes following TBI, and especially mTBI, an impact that goes beyond differences in risk of externalising problems found between sexes in individuals without TBI.

Sex differences and rates of internalising and externalising disorders have been noted in the general population. It is commonly agreed that rates of internalising disorders such as depression and anxiety tend to be higher amongst females and that structural and hormonal differences between the female and male brain may play a role in this (Hirschberg et al., 2008; Nishizawa et al., 1997; Seeman, 1997). Further, studies in the non-TBI population indicate that antisocial behaviour is far more characteristic of males than of females (Wasserman, McReynolds, Ko, Katz, & Carpenter, 2005). Though very few studies have addressed the differences between sexes and psychiatric or behavioural outcomes of paediatric mTBI, some literature indicates that sex differences may influence the expression of outcomes post-TBI. For example, the rate of in-prison behavioural infractions was greater in inmates with TBI (predominantly mild in severity). Males with TBI had a significantly increased rate of all infractions (both violent and non-violent) by 32% and females had an non-significantly increased rate by 8% (Shiroma, Pickelsimer et al., 2010). Thus, males with TBI seem more likely than females to engage in externalising behaviours.

In sum, the literature tends to demonstrate that rates of internalising disorders are higher amongst females when compared with males, but that externalising problems are more common amongst males, and this was supported in our findings. Of note, significant differences between sexes, in terms of the risk of having an internalising disorder or externalising problem, was found only in the TBI groups (both mild and moderate/severe) but not in the orthopaedic injury group. This finding gives weight to the argument that difficulty post-TBI may be expressed differently depending on sex. Due to the paucity of research on the impact of sex on outcomes of paediatric mTBI, it was necessary to turn to the literature on ADHD and sex. The results of a meta-analytic review of sex differences in ADHD suggested that females with ADHD manifested fewer externalising problems than males, on the other hand, females with ADHD had higher rates of internalising problems, such as depression and anxiety, than males (Gershon & Gershon, 2002). The significant sex differences found in the TBI

groups but not in the orthopaedic injury group in the current study highlights that sex differences found in the general population in internalising disorders and externalising problems seem to be amplified in individuals with TBI (both mild and moderate/severe). If mTBI is expressed differently across the sexes, there are important implications in terms of identification and treatment of difficulty post-mTBI.

Age at injury. Unexpectedly, this study did not find that younger age at injury was significantly associated with increased psychiatric or behavioural difficulty. In contrast, as age at injury increased, the likelihood of offending and diversions and/or convictions significantly increased by 16-18% relative to an equivalent person with one year less in terms of their age at injury. When split between each injury group (mTBI, moderate/severe TBI and orthopaedic injury), age at injury was not significantly associated with rates of the various psychiatric or behavioural difficulties in any of the groups.

Whether or not the immature brain has a greater capacity for recovery following injury than the adult brain has been much debated. While some argue that early brain injury produces milder outcomes than later brain injury (Kennard, 1936; Swain, 2006), more recent research has found that younger age at injury tends to be associated with more severe, adverse outcomes (Anderson et al., 2005; Fletcher et al., 1995; McKinlay, Grace et al., 2010; Thompson et al., 1994). Although no significant association was found between younger age of TBI and adverse outcome in the present study, a possible explanation may be simply that age at injury was examined as a continuous variable, which meant that the number of participants was spread over each age at injury, ranging from 1-17 years, and the amount of participants categorised into each year would consequently be relatively low. A greater pool of participants may be required in order to establish if any patterns existed.

Duration since injury. Unlike age at injury, increasing number of years post-injury was significantly associated with increased risk of offending, arrests and diversions and/or convictions (but not with any internalising disorders); and the risk of reporting one of these behavioural

difficulties increased by 14-17% relative to an equivalent person with one year less since their injury. None of these findings were statistically significant when split by injury group with the exception of the mTBI group, in which increasing number of years since injury was significantly associated with increased likelihood of reporting offending by 31% relative to an equivalent person with one year less since their injury. The increased likelihood of offending as the number of years post-injury increased is in all likelihood due to the longer period of time an individual would have in which to commit such offences. The findings offer further weight to the argument that research in the area needs to take into account a longitudinal perspective (of five years or more) as some behaviours, particularly offending behaviours, are more likely to become apparent over time.

The time frame between acquiring a TBI and assessment is frequently overlooked in the literature, yet the results of this present study and of other studies (McKinlay, Grace et al., 2010; Timonena et al., 2002), indicate that the duration since injury is an important variable to consider when conducting research on outcomes following paediatric mTBI. This is because deficits may not become apparent until years post-injury (McKinlay, Grace et al., 2010) and outcomes measured before maturation cannot be assumed to be stable. In this sample, the number of years post-injury ranged from 5-26 years, with a mean of approximately 11 years. The age at testing ranged between 18-31 years, with a mean age of approximately 22 years.

Alternative Explanations

It is possible that a number of factors could have contributed to the outcomes: pre-injury behavioural, family and socioeconomic characteristics may predispose certain individuals to injury in the first place and thus may explain behavioural difficulties post-TBI. However, as discussed, the use of an orthopaedic injury and moderate/severe TBI group is designed to control for such differences. An orthopaedic injury and moderate/severe TBI comparison group helps to control for pre-injury behavioural problems, and family and socioeconomic factors (Basson et al., 1991; Stancin et al., 1998; Wilde et al., 2012). For example, youth with psychiatric disorders, particularly externalising

problems such as ADHD, are more likely to engage in risky behaviour which may lead to a TBI (Gerring et al., 1998). The comparison groups also help control for the event of physical injury, hospitalisation, and family reactions to this.

Furthermore, this study sought to determine the prevalence of psychiatric and behavioural difficulties in young adults with a childhood history of mild or moderate/severe TBI compared with those with an orthopaedic injury. It is possible that some difficulties may have manifested prior to the injury (TBI or other) and were not an outcome of the injury itself; however, this seems unlikely when one considers the relatively low base rates of the psychiatric disorders reviewed in this study in the general paediatric population. It also seems unlikely due to the fact that the current study found that an increase in the number of years post-injury was significantly associated with increased risk of offending, arrests and diversions and/or convictions.

Suggestions for Future Research

It may be useful for future research to give careful consideration to the control groups used, the length of follow-up post injury, and the impact of sex on outcome. More specifically, future research will almost certainly benefit if two control groups are used: an other-injured comparison group (to control for pre-injury characteristics and circumstances that may place certain children at greater risk of injury in the first place), as well as a non-injured comparison group to represent the general population.

The long-term outcomes of paediatric mTBI remain imperfectly understood. The period spanning from birth through adolescence is marked by development and change; deficits associated with paediatric mTBI during this period may not be fully apparent. Thus to fully appreciate the potential consequences of paediatric mTBI, a longitudinal design is required with periods of follow-up until adulthood. This being said, it must be recognised that economic and time restrictions limit the extent to which this type of research can be embarked on. As an alternative to extended periods of

follow-up, it may be more suitable for research to assess the adult outcomes of paediatric mTBI and thus control for developmental processes. While this study gives weight to the argument that paediatric mTBI may increase the risk of long-term psychiatric and behavioural difficulties, further research on the matter will help improve our understanding of the topic.

Moreover, our findings have given clear evidence that sex differences in outcome should be considered when research is conducted in the area of TBI. The majority of TBI research is on male subjects and data that separates sex in analyses is been lacking (Hirschberg et al., 2008). This current study offers support for the argument that there may be a significant difference in outcome between sexes in those with TBI, above and beyond that seen in the orthopaedic injury group. Although females in the general population seem to endorse more internalising symptomology while males tend to endorse more externalising problems, it seems that this pattern is augmented in individuals with TBI when compared to controls. More research addressing the gendered outcomes of paediatric mTBI may help to uncover deficits associated with mTBI, especially those more likely to be overlooked, such as internalising disorders.

Generalisability

The study was based on data from participants who were injured before the age of 18 and thus generalisations should be limited to those who have acquired a paediatric TBI, this is because the outcomes of adult TBI may be dissimilar from outcomes from paediatric TBI.

Finally, we recruited all participants with moderate/severe TBI available from the neurosurgeons' files; however, a random selection of participants with mTBI was used. It is possible that those with mTBI who were experiencing problems were more likely to agree to take part in the study, while those without difficulties declined to take part. In this way participants in the mTBI group may comprise of a subgroup of individuals with persisting difficulties. There thus may be a

higher concentration of participants with post mTBI difficulties in this group when compared with those in the general mTBI population.

Strengths

It is important to consider the methodological strengths and weaknesses of the current research. Satz et al. (1997) identified key criteria, of which four out of six should be met in order for a study to be defined as methodologically strong. The six requirements include: 1) the presence of a control group (non-injured or other-injured); 2) longitudinal design with follow-up assessment; 3) clear definition of *mild head injury*, with no inclusion or pooling with more severe *head injuries*; 4) a sample size of 20 or more participants; 5) standardised tests; and 6) control for pre-injury risk factors. A small proportion of studies reviewed by Satz et al. (1997) met the recommended minimum four criteria in order for a study to be considered methodologically strong. This current study not only met all six of the recommendations outlined by Satz et al. (1997), but surpassed the criteria by: 1) considering the recommendation of Taylor and Alden (1990), that age at injury and duration since injury should be included as variables in research on paediatric mTBI; 2) conceptualising age as a continuous variable rather than arbitrarily creating age group categories; 3) including sex in the analysis of outcomes of mTBI.

Each of the six elements of a strong methodological design described by Satz et al. (1997) will be examined in relation to the current study.

Sample size. This study utilised a large cohort and made use of two comparison groups, an orthopaedic injury group and a moderate/severe TBI group. As a result, substantial number of participants (n= 104) were available as a comparison for the mTBI group (n=57). The relatively large overall sample size (n= 161) also meant that there was increased power and ability to detect the possibly subtle effects of mTBI; a factor that may help explain the inconsistent findings in studies with relatively smaller sample sizes.

Control group and control for pre-injury risk factors. The use of an orthopaedic injury control group offered a more representative sample than a non-injured comparison group and aided in the control of pre-injury individual characteristics and socioeconomic circumstances that may place a child at greater risk of injury (TBI or other) in the first place. Without the use of an other-injured control group, it would be difficult to determine whether reported outcomes could have resulted from the TBI or other pre-injury factors. Further, an orthopaedic and moderate/severe TBI group also controls for the emotional effects of having a traumatic injury and for the event of hospitalisation. A moderate/severe TBI group was also useful in that it allowed comparisons to be made between different TBI severities when compared to the orthopaedic injury group.

Longitudinal design. Only a few of studies have examined the adult outcomes of paediatric mTBI. This study used a longitudinal design, with outcomes examined between 5-26 years post-injury. This enabled the detection of problems that emerged during adolescence and even adulthood. To date, only nine known studies have examined the longitudinal (five or more years) psychiatric or behavioural outcomes of mTBI. Outcomes of these studies generally suggest that paediatric mTBI may result in continued psychiatric/behavioural problems in adulthood.

Clear definition of mTBI. A major difficulty with research in the area is the lack a consensus on a clear definition of mTBI and lack of criteria outlining the lower limits when defining mTBI. In this study, all three injury groups (mTBI, moderate/severe TBI and orthopaedic injury) were clearly defined and this included lower limits, whereby mTBI was required to be medically confirmed and those with injuries not severe enough to be clinically diagnosed with mTBI were not included as participants.

Different definitions of mTBI may account for some of the variability across studies' findings. The recommendation by Satz et al. (1997) that there should be no inclusion or pooling of mTBI with more severe TBI was also met. Although there was a pooled moderate/severe TBI group, this was used as a comparison with mTBI, and the mTBI group itself was not pooled with other TBI severities.

Standardised tests. Finally, this study made use of standardised measures for the diagnosis of psychiatric disorders and behavioural difficulties. The Composite International Diagnostic Interview, a series of structured interviews designed to assess mental disorders according to ICD-10 and DSM-IV was conducted to assess participants' experience of symptoms consistent with MDD, anxiety disorders (including GAD, panic attacks and panic disorder, agoraphobia, social phobia, PTSD and specific phobia), and substance abuse and/or dependence. Additionally, the Self Report Delinquency Inventory was used to collect offending data such as lifetime involvement with offending, arrests, and diversions and/or convictions.

In summary, this current study met all six of the recommendations outlined by Satz et al. (1997) and surpassed the recommended criteria by considering age at injury, duration since injury and sex.

Limitations

It is appropriate to consider the limits in the present study. Firstly, pre-injury factors were not, and cannot necessarily be obtained when assessing the paediatric mTBI sample as behavioural or psychiatric difficulties (or lack thereof) may not be apparent in children who were injured at a younger age. Although, as per the design of the research, details of pre-injury characteristics were not collected, it is expected that the use of an orthopaedic injury and moderate/severe TBI group will control for any characteristics that may make injury (paediatric TBI or other injury) more likely, and also control for the emotional effects of having a traumatic injury. This control for pre- and post-injury confounding variables would not be possible by simply comparing the mTBI group to a non-injured comparison group.

A further limitation is that there was no follow-up after the initial assessment. This factor may be offset by the longitudinal design of the study, and the mean number of years post-injury was approximately 11 years. Moreover, the fact that all participants were tested over the age of 18, with a mean age of approximately 22 years diminishes the impact of this. Satz et al. (1997) recommend a

longitudinal design with follow-up assessment, but the duration of the follow-up is not specified. Though no follow-up was conducted in this study, it is thought that a longitudinal design of over five years post-injury, and into adulthood, offers richer information than a relatively short-term follow-up, i.e. six months post-injury.

Another limitation to the study is that the data was retrospective in nature and issues such as accurate recall and bias are of importance here. In terms of bias, the psychiatric and behavioural problems are more likely to be underreported than exaggerated (Kessler & Ustun, 2004). Furthermore, participants may not be able to accurately recall symptoms and experiences, especially those with moderate/severe TBI. This being said, if participants have difficulty remembering past symptoms and experiences, it seems more likely that they would under-report rather than over-report psychiatric and behavioural problems.

In sum, while no pre-injury information was obtained from participants, the use of an orthopaedic injury and moderate/severe TBI group will most likely have controlled for differences in pre- and post-injury characteristics. Further, the long longitudinal design of on average 11 years post-injury is thought to control for developmental changes that may occur over time in terms of the presentation of psychiatric and behavioural difficulties. And while memory biases and forgetting on the part of participants may have impacted on the accuracy of the results, it seems feasible that psychiatric and behavioural problems would have been under-reported rather than over-reported.

Implications and Clinical Significance

The vast majority of all TBIs are mild, and the vast majority of injuries of this type occur in the youth population (Feigin et al., 2013; McKinlay et al., 2008), yet our understanding of the long-term psychiatric and behavioural outcomes of paediatric mTBI is far from complete. Such knowledge is important to consider when conducting an informed assessment of psychiatric and behavioural disturbances post-paediatric mTBI and a better understanding of risk factors may lead to more timely

identification and treatment of those afflicted. The somewhat unpredictable pattern of outcomes of paediatric mTBI limit health professionals in their ability to identify young people at high risk for adverse outcomes (Max et al., 2011). This study contributes to the much needed and gradually growing body literature on the topic.

The findings of this research suggest that a proportion of individuals who have suffered paediatric mTBI are at significantly increased risk for long-term psychiatric difficulties. Furthermore, these findings indicate participants with mTBI were at greater risk of internalising disorders than those with orthopaedic injury and the risk of experiencing an internalising disorder by those with mTBI is even greater than the risk faced by those with moderate/severe TBI. Additionally, the risk of externalising problems was elevated in those with mTBI when compared to the orthopaedic injury group, but this was not significant, and was not as elevated as the risk faced by those with moderate/severe TBI. Paediatric mTBI seems to be particularly associated with increased risk of internalising disorders including MDD and various anxiety disorders.

While it has been reported by some that mTBI does not result in adverse long-term outcomes, these results suggest otherwise and show that it is important that health care practitioners and care givers are aware of the increased risk of internalising disorders following mTBI so that symptoms are not over looked. Furthermore, the risk of externalising behaviours was significantly increased in those with moderate/severe TBI, but not mTBI, when compared with the orthopaedic injury group and appropriate interventions may be useful for at-risk individuals (i.e. those with moderate/severe TBI). The need for this is made clear by Leon-Carrion and Ramos (2003), who reported in their study that a history of untreated paediatric *head injuries* was what differentiated the violent from non-violent prisoners. Further, it is important to identify treatable co-morbidities resulting from TBI, such as MDD, in order to improve outcome post-injury. For example, in adults with mTBI, successful treatment of depression resulted in significant alleviation of cognitive impairment (Fann et al., 2001).

Clinical implications for sex differences in outcome. The results indicate a clear and significant sex differences in terms of the risk of reporting internalising versus externalising problems; whereby females with TBI (both mild and moderate/severe) tended to be significantly more liable than males to endorse internalising disorders and males with TBI, and particularly mTBI, tend to be significantly more liable than females to endorse externalising problems. A similar difference between sexes was found in the orthopaedic injury group but it was not significant for any of the internalising disorders or externalising problems, thus suggesting that the differences between sexes in terms of psychiatric disorders/behavioural problems is amplified in individuals with TBI compared with those with orthopaedic injuries.

The role that sex plays in the expression of outcome will be important in identifying and treating the effects of paediatric TBI (both mild and moderate/severe) and awareness of the risk factors for internalising disorders (such as females with mTBI) and externalising problems (such as males with mTBI) may aid in early identification and intervention of those at-risk. Further, such knowledge may help to ensure that health practitioners do not focus on observable externalising behaviours and overlook the often more subtly expressed internalising disorders.

A better understanding of the psychiatric and behavioural outcomes following paediatric mTBI and the risk factors for each problem, will in all probability have implications for assessment and intervention and could help prevent major lifelong difficulties, while optimising outcomes for the increasing number of children and adolescents who experience mTBI.

Conclusion

Traumatic brain injury is a common form of injury in New Zealand and globally (Cassidy et al., 2004; Feigin et al., 2013), with the highest incidence of all TBI events occurring in the paediatric population (McKinlay et al., 2008). Feigin et al. (2013) calcuated the total incidence of all TBIs in

New Zealand as 790 cases per 100 000 people, of which 95% were classified as mild. The risk of acquiring mTBI was 18 times greater than the risk for moderate to severe TBI. Children, adolescents and young adults made up approximately 70% of all TBI cases.

Mild TBI acquired in the paediatric population is not uncommon, yet there is much variability in reported psychiatric and behavioural outcomes following paediatric mTBI and the long-term outcomes (i.e. five or more years) remain imperfectly understood. This body of work contributes to the mounting evidence that a proportion of individuals who acquire mTBI in their youth are at higher risk for the development of adverse outcomes, in particular, internalising disorders, than those without TBI and importantly, are at even greater risk than those with moderate/severe TBI. Mild TBI was not significantly associated with risk of externalising problems, although the risk was significantly increased for those with moderate/severe TBI when compared to the orthopaedic injury group.

Above and beyond enhancing our understanding of the difficulties that those with paediatric mTBI may experience, this study also sheds light on the sex difference in terms of expression of such difficulties, and a clear pattern can be seen whereby females with mTBI are particularly, and significantly at greater risk of internalising disorders while males with mTBI are more likely to present with externalising problems. Such an understanding is crucial to assist healthcare professionals such as doctors and psychologists in the care of affected individuals and in the education of parents. It is critical, too, for the effective assessment and identification of problems in those who have acquired a paediatric mTBI, as well as for therapeutic intervention in their lives.

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Health and Disability Ethics Committees

Upper South B Regional Ethics Committee
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Email: uppersouth_ethicscommittee@moh.govt.nz

19 January 2011

Dr Audrey McKinlay
Christchurch Brain Research Group
Department of Psychology
University of Canterbury
Private Bag 4800, Christchurch

Dear Dr McKinlay

Ethics ref: **URB/08/04/017** (please quote in all correspondence)
Study title: Adult outcomes of childhood traumatic brain injury

Thank you for submitting a progress report for the above study. The Chairperson of the Upper South B Regional Ethics Committee, under delegated authority, has confirmed ethical approval for a further 12 months until 31 January 2012.

The Committee looks forward to receiving a further progress report at that time.

Yours sincerely

Diana J. Whipp

Mrs Diana Whipp
Administrator Upper South B Regional Ethics Committee
Diana_Whipp@moh.govt.nz

Date

Name
Address

Dear.....,

We are doing some NEW research looking at adult outcomes for people who experienced a childhood traumatic brain injury (an injury to the head that resulted in concussion or other neurological symptoms). We would very much like your help if you can.

Please look at the enclosed information sheet. If you are willing to have Audrey McKinlay conta you about this research, please either call her or place the reply slip in the pre-paid addressed envelope and then post that back to us.

Thank you for your time.

Mr Martin MacFarlane MD
Neurosurgeon

College of Science

Department of Psychology
Tel: +64 3 364 2902, Fax: + 64 364 2181
Email:

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Information Sheet: For potential participants who experienced a traumatic brain injury in childhood

Project Title: **Adult outcomes of childhood traumatic brain injury**

Name:

Address: Date:

We would like to invite you to take part in a new research study. Researchers at the University of Canterbury (Randolph Grace, Audrey McKinlay and Derek Roger) are conducting this study in collaboration with neurosurgeon, Dr. Martin MacFarlane and child health researcher's Professor David Fergusson and John Horwood. This study will provide information on adult functioning (including attention and memory, employment status and psychiatric history) in people with who experienced a traumatic brain injury during childhood. These responses will be compared with those obtained from people who experienced an orthopaedic injury during childhood.

This information sheet has been forwarded to you by the neurosurgeon at Christchurch Hospital. If you are interested in taking part in the study, please contact Audrey McKinlay (366 7001 Ext. 7885).

If you agree to participate in this research, please note that you are free to withdraw at any stage. If you choose to withdraw, you do not need to give a reason and this will not affect your future care or treatment. If you return the reply slip, Audrey McKinlay {or named research assistant} will telephone you to see if you are interested in taking part in this study. She will be pleased to answer any questions you may have at this time. Please feel free to take up to a month to decide if you would like to help.

If you agree to help we would ask you to attend a single two hour session at the University of Canterbury. During this time you will be asked a number of questions to provide some general information about your adult functioning. You would also participate in a brief set of neuropsychological testing. We have provided more detail about what the type of information we would ask and type of testing that would be conducted in the section below:

General Information

You will be asked to answer a number of questions regarding your current status, including living arrangements, employment and education status, alcohol use. We will also ask for information regarding your psychiatric history (e.g. whether you have suffered from depression) and any interactions you may have had with the police. This section of the process will take about one hour.

Neuropsychological Testing

We will also ask you to participate in some standard neuropsychological testing. The various tests that we will ask you to participate in will follow standard procedures. This testing will provide information about skills such as, ability to inhibit responses, short and long term memory and planning. All of the tests or subtests require a short period of concentration (5-10 minutes). This section of the process will also take about one hour

Reimbursement

All participants will be reimbursed $20 for each visit towards transport costs (or the cost of a taxi, if required, in the Christchurch region).

Confidentiality

Please note that all information provided for this study will be treated in the utmost confidence. All personal information will be securely stored, accessible only by the principal investigators of this study. Your identity will not be disclosed in any reports based on information from this study.

Information regarding the findings of this study

Although individual results will be kept strictly confidential, a summary of the findings from this research will be made available to all of the participants and we will be pleased to send you a copy on completion of the study. The overall results gathered will be used for the purposes of this study and will contribute to the scientific knowledge on the long-term outcomes of childhood traumatic brain injury. The information obtained may be added to that obtained in future studies, because it is necessary to have large data-sets to improve our accuracy in describing the overall effects of traumatic brain injury

Support Person

You are invited to bring a partner/friend /family member or support person with you to any visit. An adjacent room will be available for them to wait if you desire.

Significant Other

If you consent, we would also like you to nominate a person who knows you well and could provide some information about your general demeanour and every day routines. A questionnaire would be sent to this person who would reply by post.

Participation

Your participation in the study is entirely voluntary. You do not have to answer all the questions in the study and you are free to withdraw at any time for any reason.

If you have any questions or concerns about any aspect of this study you are welcome to contact Audrey McKinlay (366 7001 Ext. 7885)

If you have any queries of concerns about your rights as a participant in this study you may wish to contact a Health and Disability Advocate (03) 377 7501 or 0800 377 766 (outside of Christchurch).

In the unlikely event of a physical injury as a result of your participation in this study, you will be covered by accident compensation legislation within its limitations. If you have any questions about ACC please feel free to ask the researcher for more information before you take part in this study.

This study has received ethical approval from the Canterbury Ethics Committee and we are committed to treating all of the study participants in a fair and ethical manner.

We would greatly value your help. Thank you for considering this request.

<u>If you are interested in taking part in the study, please feel free to contact me by phone to confirm or return the reply slip in the self addressed envelope.</u>

Audrey McKinlay (366 7001 Ext 7885)
Clinical Psychologist/Research Fellow

College of Science

Department of Psychology
Tel: +64 3 364 2902, Fax: + 64 364 2181
Email:

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Information Sheet: For potential participants who experienced orthopaedic injury during childhood (control group)

Project Title: **Adult outcomes of childhood traumatic brain injury**

Name:

Address: Date:

We would like to invite you to take part in a new research study. Researchers at the University of Canterbury (Randolph Grace, Audrey McKinlay and Derek Roger) are conducting this study in collaboration with neurosurgeon, Dr. Martin MacFarlane and child health researcher's Professor David Fergusson and John Horwood. This study will provide information on adult functioning (including attention and memory, employment status and psychiatric history) in people with who experienced a traumatic brain injury during childhood.

Traumatic brain injury results from a blow or jolt to the head of sufficient severity to alter brain functioning. This is sometimes seen in symptoms such as vomiting, loss of consciousness, or loss of memory. Traumatic brain injury is one of the most frequent causes of injury during childhood. However, there is very little information regarding the long-term consequences of these injuries. To understand the long term effects of these injuries, we need to compare the abilities of individuals who have experienced a traumatic brain injury during childhood with that of "healthy controls" who do not have a traumatic brain injury.

This is why we are contacting you to ask for your help in this important work. We are specifically asking people who have experienced an orthopaedic injury to act as controls because we believe that children who experience any type of injury tend to be more risk taking than those who do not. This approach will make our comparisons better.

If you agree to participate in this research, please note that you are free to withdraw at any stage. If you choose to withdraw, you do not need to give a reason and this will not affect your future care or treatment. If you return the reply slip, Audrey McKinlay {or named research assistant} will telephone you to see if you are interested in taking part in this study. She will be pleased to answer any questions you may have at this time. Please feel free to take up to a month to decide if you would like to help.

If you agree to help we would ask you to attend a single two hour session at the University of Canterbury. During this time you will be asked a number of questions to provide some general information about your adult functioning. You would also participate in a brief set of neuropsychological testing. We have provided more detail about what the type of information we would ask and type of testing that would be conducted in the section below:

General Information

You will be asked to answer a number of questions regarding your current status, including living arrangements, employment and education status, alcohol use. We will also ask for information regarding your psychiatric history (e.g. whether you have suffered from depression) and any interactions you may have had with the police. This section of the process will take about one hour.

Neuropsychological Testing

We will also ask you to participate in some standard neuropsychological testing. The various tests that we will ask you to participate in will follow standard procedures. This testing will provide information about skills such as, ability to inhibit responses, short and long term memory and planning. All of the tests or subtests require a short period of concentration (5-10 minutes). This section of the process will also take about one hour

Reimbursement

All participants will be reimbursed $20 for each visit towards transport costs (or the cost of a taxi, if required, in the Christchurch region).

Confidentiality

Please note that all information provided for this study will be treated in the utmost confidence. All personal information will be securely stored, accessible only by the principal investigators of this study. Your identity will not be disclosed

in any reports based on information from this study.

Information regarding the findings of this study

Although individual results will be kept strictly confidential, a summary of the findings from this research will be made available to all of the participants and we will be pleased to send you a copy on completion of the study. The overall results gathered will be used for the purposes of this study and will contribute to the scientific knowledge on the long-term outcomes of childhood traumatic brain injury. The information obtained may be added to that obtained in future studies, because it is necessary to have large data-sets to improve our accuracy in describing the overall effects of traumatic brain injury

Support Person

You are invited to bring a partner/friend /family member or support person with you to any visit. An adjacent room will be available for them to wait if you desire.

Significant Other

If you consent, we would also like you to nominate a person who knows you well and could provide some information about your general demeanour and every day routines. A questionnaire would be sent to this person who would reply by post.

Participation

Your participation in the study is entirely voluntary. You do not have to answer all the questions in the study and you are free to withdraw at any time for any reason.

If you have any questions or concerns about any aspect of this study you are welcome to contact Audrey McKinlay (366 7001 Ext. 7885)

If you have any queries of concerns about your rights as a participant in this study you may wish to contact a Health and Disability Advocate (03) 377 7501 or 0800 377 766 (outside of Christchurch).

In the unlikely event of a physical injury as a result of your participation in this study, you will be covered by accident compensation legislation within its limitations. If you have any questions about ACC please feel free to ask the researcher for more information before you take part in this study.

This study has received ethical approval from the Canterbury Ethics Committee and we are committed to treating all of the study participants in a fair and ethical manner.

We would greatly value your help. Thank you for considering this request.

If you are interested in taking part in the study, please feel free to confirm with me by phone or return the reply slip in the self addressed envelope.

Audrey McKinlay (366 7001 Ext 7885)
Clinical Psychologist/Research Fellow

Adult Outcomes of Childhood Traumatic Brain Injury

REPLY SLIP

I have read the information sheet and would be willing to be contacted regarding participation in the project " Adult Outcomes of Childhood Traumatic Brain Injury".

CONTACT DETAILS:

Name _____

Telephone Number: _____

Most convenient time to contact: _____

Consent Form

Project Title: Adult Outcomes of Childhood Traumatic Brain Injury

I have been invited to take part in this study adult outcomes of childhood traumatic brain injury. An information sheet has been provided on the aims and purpose of the study. I have read and understood the information it contained. I have been given an opportunity to discuss the study. I am satisfied with the answers that have been given. I have had time to consider whether to take part.

I understand that:

- Participation in the study is voluntary (my choice)
- I am free to withdraw from the study at any time and this will in no way affect my future healthcare.
- I am free to refuse to answer any questions that I do not want to answer.
- This study has approval from the Canterbury Ethics Committee.
- My participation in the study is confidential and no information that could identify me will be used in any reports that may be generated from this study.
- if any assessments raise concern about my health this will be conveyed to me and my General Practitioner

I have been provided with information regarding who to contact if I have any concerns regarding the study.

(All participants) I would like to receive a copy of the results of this study YES / NO

I _____ hereby consent to take part in this study.
(full name)

Signature:_____ Date: _____

Researchers: Audrey McKinlay, Randolph Grace, John Horwood, Martin MacFarlane, Derek Roger, David Fergusson.

Contact phone number: Audrey McKinlay (366 7001 Ext. 7885)

Project explained by: _____

Project role: _____

Signature: _____ Date: _____

AMcK Page 1 16/03/2008